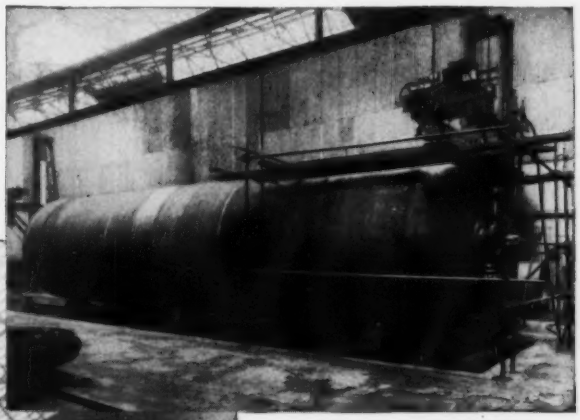
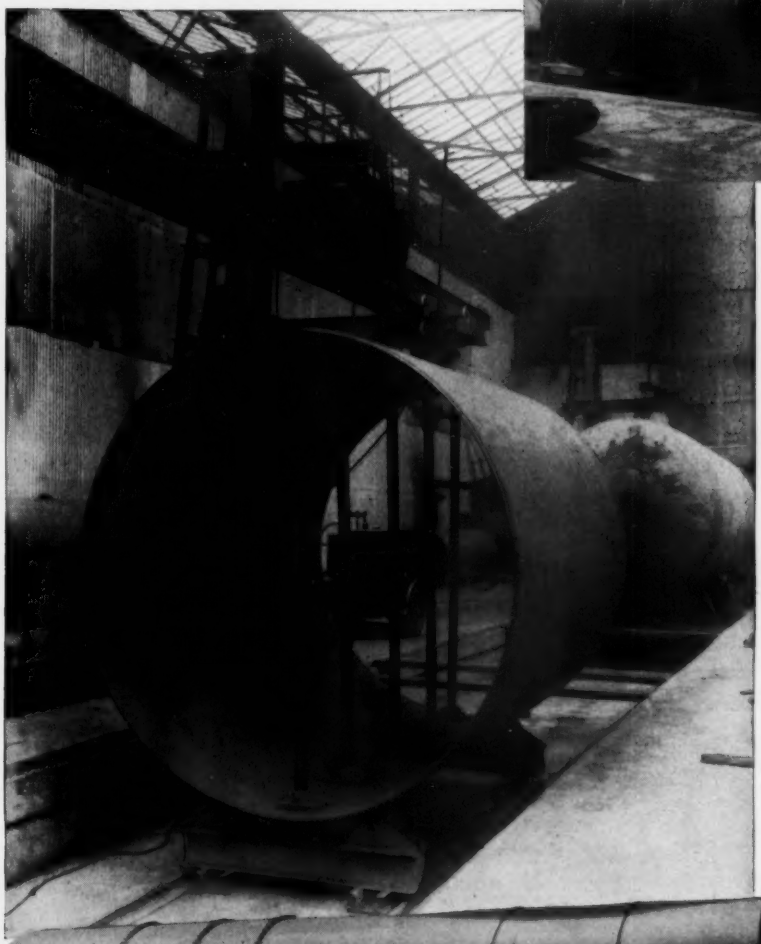
PROPANE TANK





The illustrations show one of a number of similar vessels forming part of a contract for the East Halton, Lincs., Oil Refinery, of

HERBERT GREEN & COMPANY LTD.

These vessels are 10′ 0″ inside diameter x 45′ 0″ long x 1.5/16″ thick plate, for a working pressure of 250 lbs/sq.inch. They each weigh 40 tons and are fabricated by the Babcock Class 1 Fusion Welding Process, which provides proof of safety in advance of use and in which all tests may be witnessed by independent inspectors.

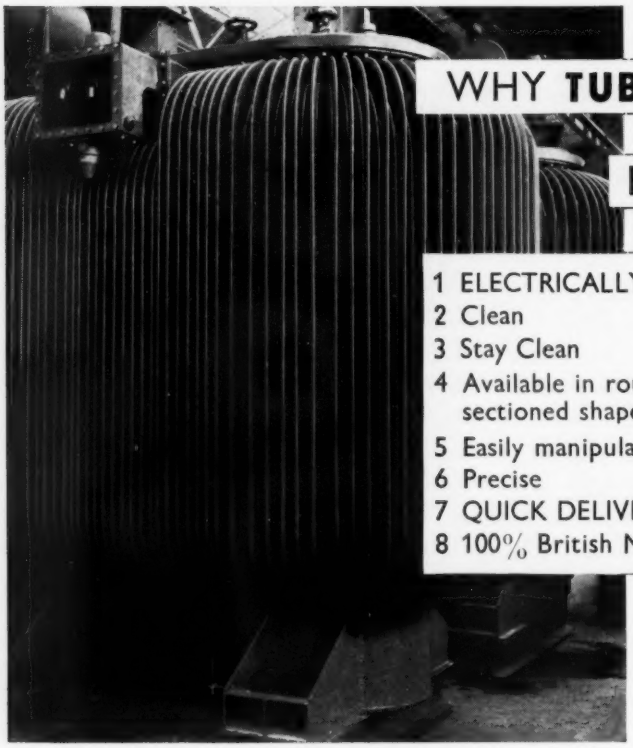
The illustrations showing the vessel in course of manufacture are of interest as the merits of this process have been so widely recognised as to necessitate during the past year two extensions to our Class 1 Welding Shop, and now a completely new and greatly enlarged Shop is in course of construction.

The process is particularly applicable to all classes of vessels required to withstand high pressures and temperatures, and is approved by Lloyds' Register and the leading Insurance Companies.

May we send you details of this welding process ?

BABCOCK & WILCOX LTD. BABCOCK HOUSE, FARRINGDON ST., LONDON, E.C.4

Rytad



WHY **TUBE PRODUCTS** TUBES

FOR TRANSFORMERS?

1 ELECTRICALLY WELDED	Yes ✓
2 Clean	Yes ✓
3 Stay Clean	Proved ✓
4 Available in round and sectioned shapes	Yes ✓
5 Easily manipulated	Proved ✓
6 Precise	Yes ✓
7 QUICK DELIVERY	Proved ✓
8 100% British Material	Yes ✓

TUBE PRODUCTS LIMITED
OLDBURY · BIRMINGHAM

TE6

PACKINGS AND JOINTINGS

WALKER'S LION PACKING

"GASKOID" Jointing is permanently Oil and Petrol resisting. The material is tough yet supple and is used extensively on very important jobs. Write for Free Trial sample.

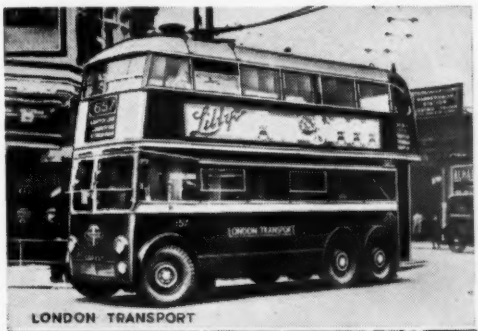
Walker's **MOULDED VALVES** have a reputation for quality. They can be supplied for any service. We specialise in the manufacture of Rubber Diaphragms.

"KROMYDE" is a high grade lubricated leather packing for service in oil at low temperature and pressure.

GOLDEN "WALKERITE" is recognised as the "King" of H.P. Steam Jointings.

WRITE FOR CATALOGUE H.6.

JAMES WALKER & CO., LTD.
"LION" WORKS · WOKING · SURREY
PHONE. WOKING 1040 GRAMS. LIONCELLE


LONDON TRANSPORT

Keeping pace with TROLLEY BUS OPERATION

NEWCASTLE-ON-TYNE

PORTSMOUTH

SYDNEY

BRADFORD

The modernisation of public-service transport is being carried out in many important cities. Numerous Municipalities have extended their existing Trolley bus services by placing additional "A.E.C.-English Electric" vehicles into operation. Others are converting older systems to the operation of these smooth-running, silent and efficient vehicles. In most cases orders were placed only after exhaustive tests had been made.

Full details gladly sent on request.

THE ENGLISH ELECTRIC COMPANY LTD.,
Traction Dept., Bradford.

THE ASSOCIATED EQUIPMENT CO., LTD.,
Southall, Middlesex.

SUPERIORITY

comes from infinite technical care —and experience

TAYLOR TUNNICLIFF PORCELAIN

Taylor Tunnicliff & Co. Ltd., 110 Cannon St., London, E.C.4, Factories at Hanley, Stone & Longton, Staffs. Tel.: Mansion House 7211-2 & Hanley 5272-4.

TAS/Tt.2

STEEL SHEETS

FOR ALL PURPOSES

We can supply your requirements immediately from stock at the lowest possible prices.
——Highest quality only.——

SHEETS SPECIALLY SHEARED FOR CUSTOMERS' REQUIREMENTS DOWN TO 3".

STEEL, PLAIN & CHEQUERED PLATES
STEEL SECTIONS · IRON & STEEL
MERCHANT BARS · FLITCH PLATES
HOOPS, ETC.

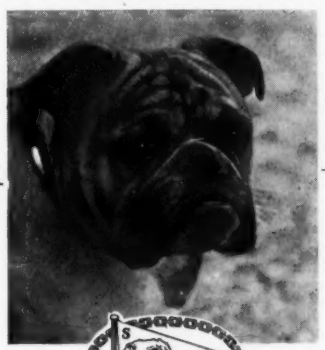
Full range of sizes and large tonnages always in stock.

MONTHLY STOCK LIST MAILED ON APPLICATION.

HALL BROS (West Bromwich) LTD.
EAGLE WORKS · GREETS GREEN
WEST BROMWICH

Telephone: No
Tipton 1611 (5 lines)

Telegrams: Eagle, West Bromwich.

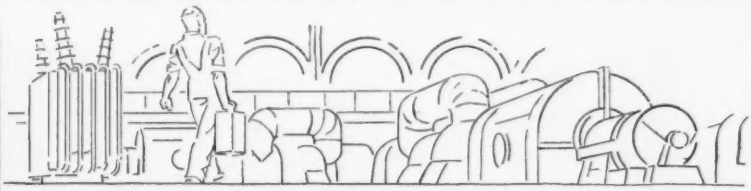


TRADE MARK

Quality will tell!

THE STERLING VARNISH Co. Ltd.

Telephone: Trafford Park 2231 and 2232
Telegrams: "Dielectric, Manchester."



FIRST IN 1891. FOREMOST EVER SINCE.

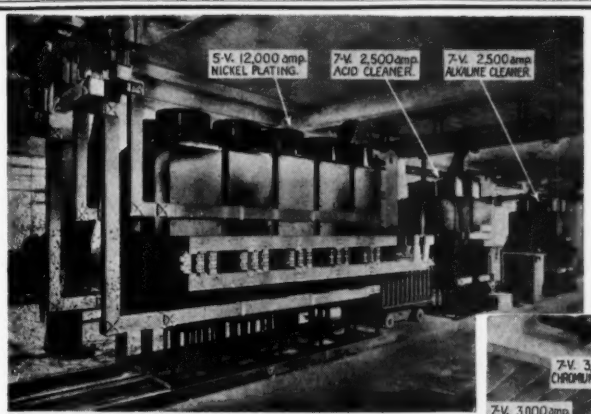
Undoubtedly the finest **Insulating Varnishes** in the World. Used by all the largest electrical manufacturers in Europe and America with every success.

Sterling Paints and Enamels are also being widely adopted by all trades.

Sterling Oil Synthetic-Resin Insulating Varnishes are being widely adopted for various purposes.

STERLING
INSULATING VARNISHES PAINTS & ENAMELS

FRASER RD. TRAFFORD PARK, MANCHESTER 17.



The World's Largest Electro-Plating Rectifier!

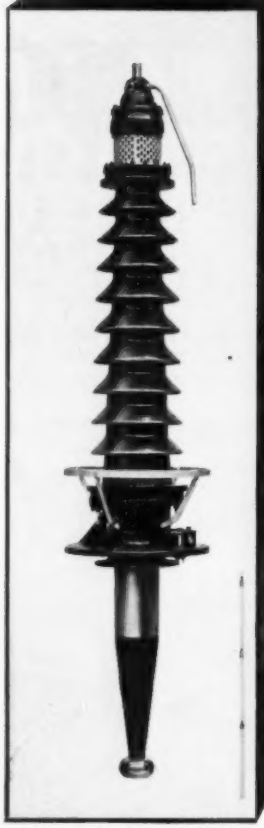
Recognised throughout the world as the most reliable and efficient . . . relied upon by railways, the Central Electricity Board, etc. . . . the Westinghouse Metal Rectifier is being increasingly used by many Companies for their electro-plating current supply, owing to the reduction in operating costs which are effected with the elimination of maintenance and the saving in power consumption. The photographs show an installation of 28,000 amperes at the Hercules Cycle & Motor Company, by whose permission they are reproduced.

WESTINGHOUSE BRAKE & SIGNAL CO., LTD.,
82, YORK ROAD, LONDON, N.1

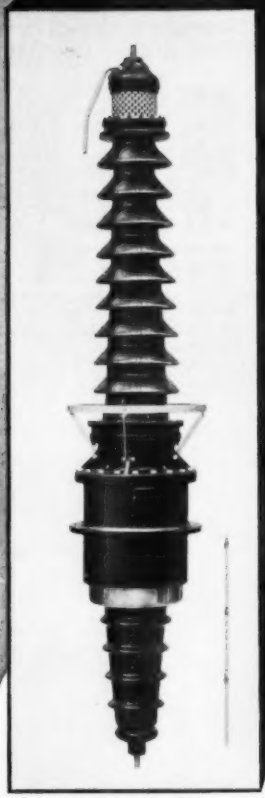
WESTINGHOUSE
METAL RECTIFIERS

PAXOLIN REG^D BUSHINGS

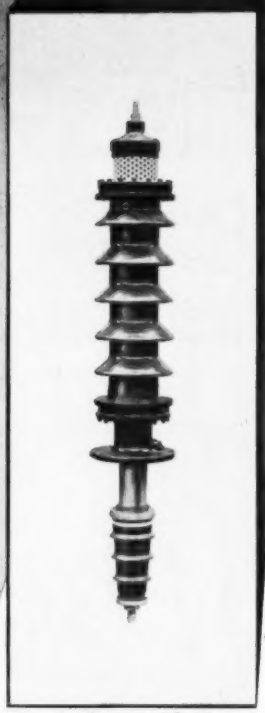
BRITISH MADE



154 kV. Outdoor Condenser Type Transformer Bushing (Oil Filled).



154 kV. Outdoor Condenser Type Oil Circuit Breaker Bushing (Oil Filled).



66 kV. Outdoor Condenser Type Oil Circuit Breaker Bushing (Oil Filled).

The BUSHINGS illustrated above are of Condenser Type, the space between the Bushing and the Porcelain being filled with an insulating oil. The construction is such that the use of cement is avoided and any mechanical strain imposed upon the Bushing is taken by the conductor and not communicated to the porcelain.

PAXOLIN — the leading British-made Varnish-Paper Insulation — supplied in the form of Boards, Panels, Tubes and Cylinders, as well as Insulators and Bushings.

THE MICANITE & INSULATORS CO LTD

Electrical Insulation Engineers and Manufacturers

WALTHAMSTOW MIC **LONDON, E.17**

"MARELLI"

(Regd. Trade Mark)

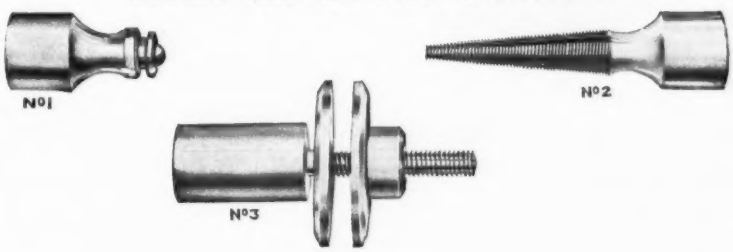
FRACTIONAL HORSE POWER

POLISHING AND GRINDING MOTORS

(A.C. 2-SPEED MODEL)

PARTICULARS OF OTHER MODELS
AVAILABLE ON APPLICATION

CHUCKS FOR USE WITH THE ABOVE



PRICES ON APPLICATION TO :

MARELLI & Co. LTD.

ARTILLERY HOUSE, ARTILLERY ROW,
VICTORIA STREET, LONDON, S.W.1.

Telephone : VICTORIA 3476/7. Telegrams & Cables : "MARELLI, LONDON."

THE "NEW CENTURY" CONTINUOUS PHOTO COPIER

MODEL No. N.C. 28.

THE MOST EFFICIENT MACHINE EVER PRODUCED, WITH A CAPACITY FOR OVER 6,000 Double Elephant BLUE PRINTS PER DAY. EMBODYING UNIQUE FEATURES IN DESIGN AND PERFORMANCE.

Patentees and Sole Manufacturers:

E. N. MASON & SONS, LIMITED

PHOTO PRINTING EQUIPMENT SPECIALISTS

ARCLIGHT WORKS · COLCHESTER · ENGLAND

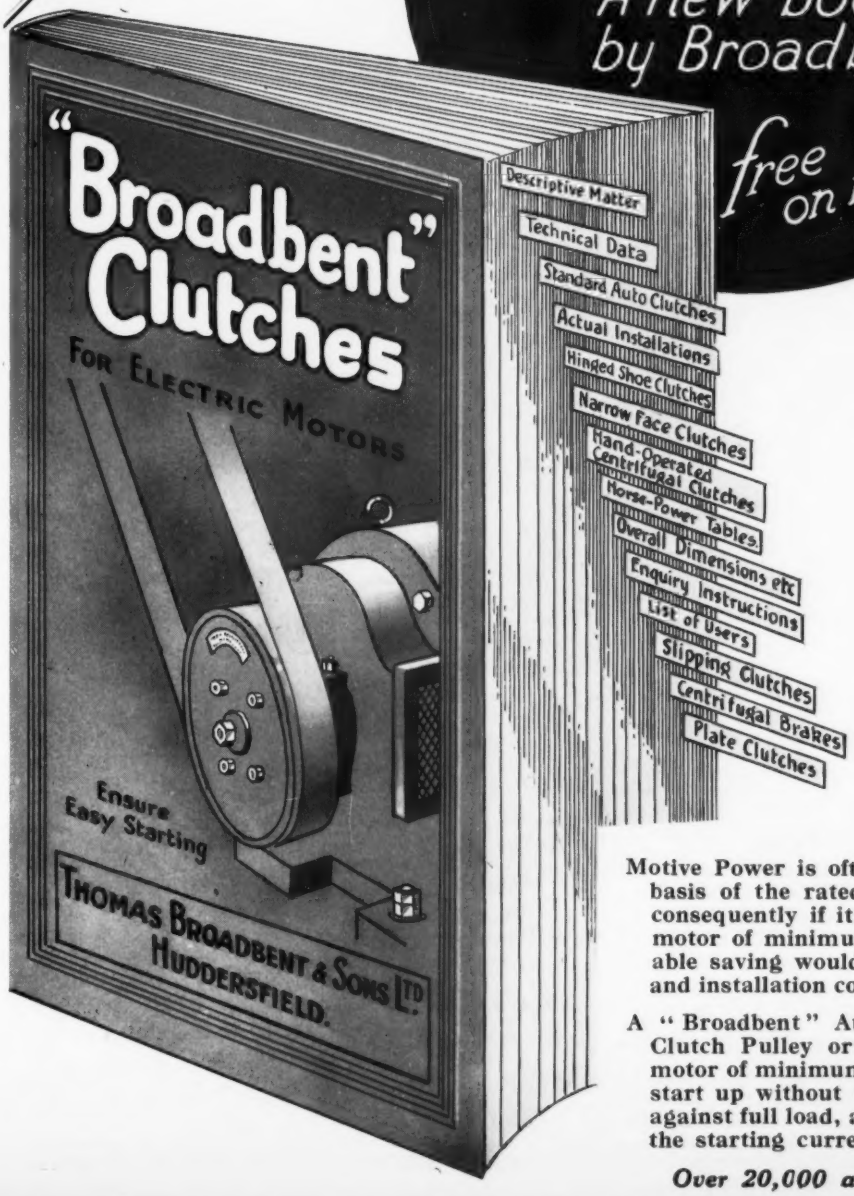
LONDON — BIRMINGHAM — MANCHESTER — NEWCASTLE-ON-TYNE

AUTOMATIC CENTRIFUGAL CLUTCHES HAVE BEEN ONE OF THE OUTSTANDING ENGINEERING SUCCESSES OF RECENT YEARS

USEFUL DATA ON CLUTCHES

A new booklet by Broadbent

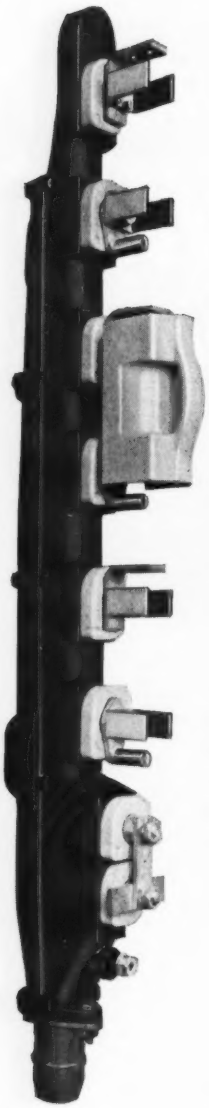
free on request



Motive Power is often purchased on the basis of the rated H.P. of the motor, consequently if it is possible to use a motor of minimum power a considerable saving would be effected in power and installation costs.

A "Broadbent" Automatic Centrifugal Clutch Pulley or Coupling enables a motor of minimum overload capacity to start up without the slightest trouble against full load, and definitely reduces the starting current consumption.

Over 20,000 already supplied.



3-phase, 4-wire Tailless Type Unit. Wire or Cartridge fuses up to 500 amps.

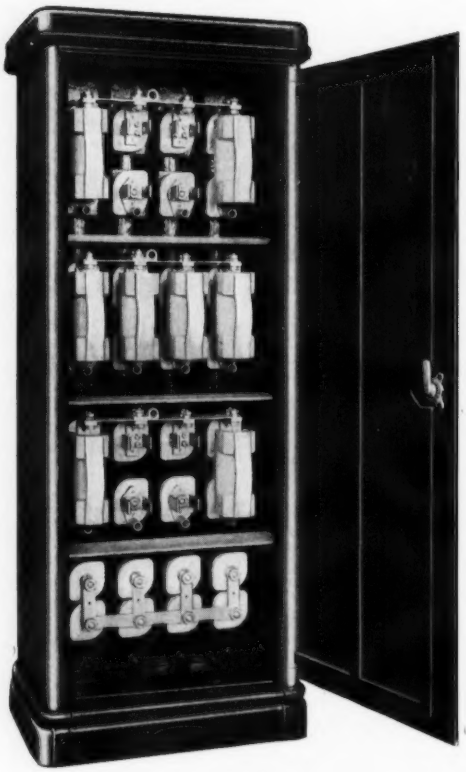
SIEMENS

FEEDER PILLARS

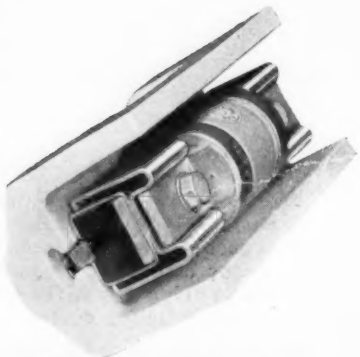
(Patent No. 336,752)

STANDARD UNIT, 3 & 4-WIRE

THE UNIT is of cast-iron divided on the cable line, with screwed-on back. The casting is so designed that the neutral base is set forward to allow free running of cable cores. Substantial porcelain insulators are fixed from the front. All fuse contacts are connected from the front and are easily renewed without breaking down the cable joint. Cable eyes only are removed for jointing and this does not disturb the alignment of the fittings. There are no bolted joints under compound and no live metal parts at the back. All current-carrying parts are of high conductivity copper and tinned.



4-way, 3-phase, 4-wire Pillar.



Porcelain Handle with Cartridge fuse.

FUSES

(Patent Nos. 189,684 and 429,806)

The handles and contacts are constructed so that they can be used with copper wire fuses through an asbestos tube, or with "English Electric" Cartridge Fuses "T" Type without any alteration. The Fuse handles are stocked in three sizes: 150, 300 and 500 amps.

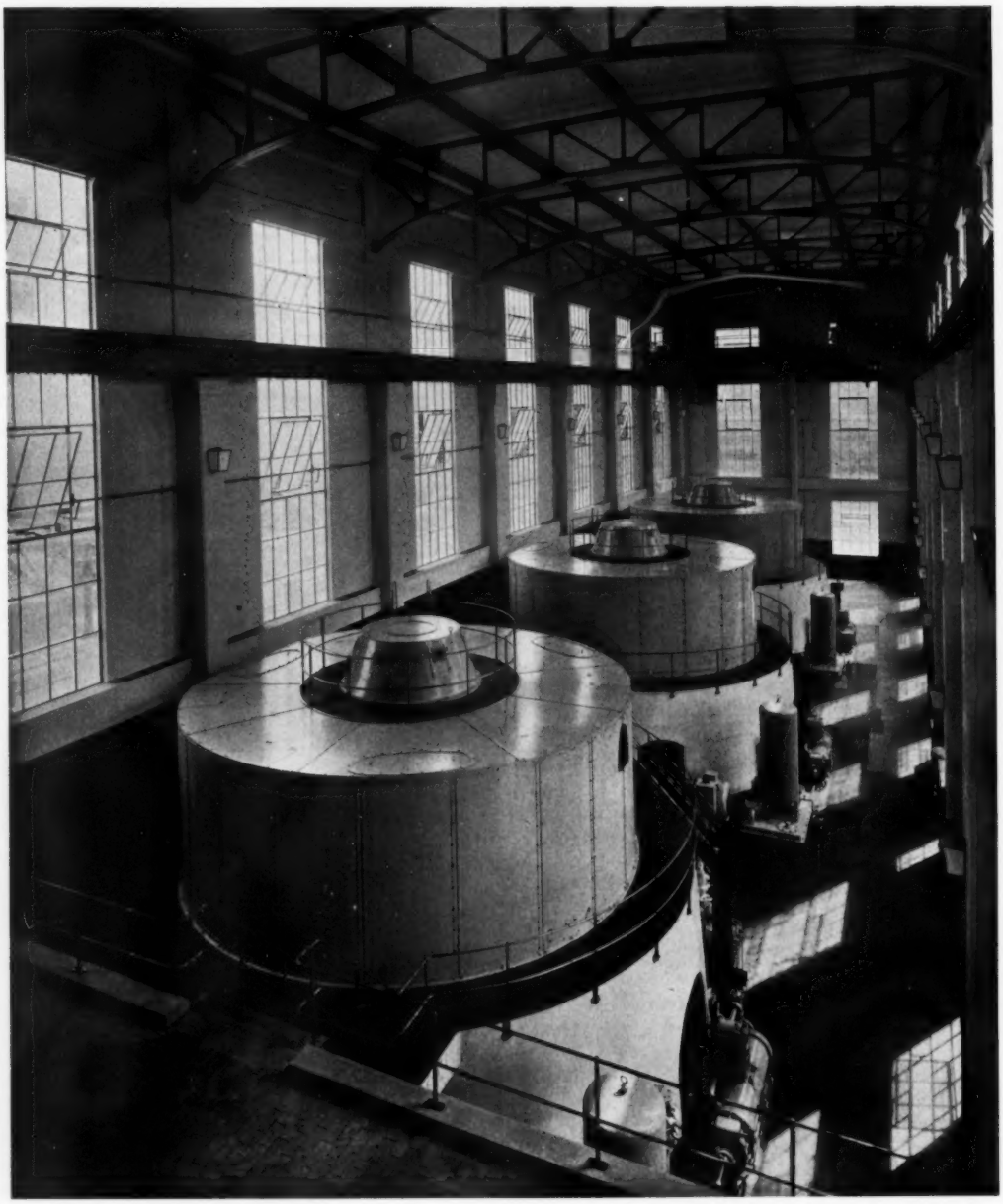
SIEMENS BROTHERS & CO., LTD.

WOOLWICH, LONDON, S.E.18.

The ENGLISH ELECTRIC JOURNAL

Queen's House from Lincoln's Inn Fields.

All rights of republication, including translation of articles, are reserved.



The Tongland Power Station of the Galloway Water Power Company, containing three 11,000 kW. Water Turbine-driven Alternators.

The English Electric Journal

Vol. VIII. No. 1 FEBRUARY, 1936 One Shilling.

CONTENTS.

PAGE

THE GALLOWAY WATER POWER SCHEME - - - - - 5

THE ELECTRICAL EQUIPMENT OF TROLLEY VEHICLE ROUTES - 13

RECENT DEVELOPMENTS IN SINGLE PHASE MOTORS - - - 19

THE APPLICATION OF DIESEL-ELECTRIC TRACTION - - 23

All Communications respecting Editorial Contents should be addressed to THE EDITOR, THE ENGLISH ELECTRIC JOURNAL, THE ENGLISH ELECTRIC COMPANY LIMITED, STAFFORD.

EDITORIAL.

Our frontispiece gives an excellent impression of the three 11,000 kW. water turbine-driven generating sets in the Tongland Power Station of the Galloway Water Power Company, which has recently been put into commission.

This issue commences with the first of a series of articles by Mr. H. L. Bazalgette, which will describe and illustrate the hydro-electric scheme of the Galloway Water Power Company, for which the English Electric Company are supplying the turbine generating plant aggregating 102,000 kilowatts.

The Company is exceptionally well placed to carry out comprehensive hydro-electric schemes of any magnitude. It is the only British manufacturer of complete large water turbine sets (including both turbines and generators) and has equipped large hydro-electric stations in Great Britain and in many other parts of the world. Such contracts have included, not only turbines and generators of the vertical and horizontal types, but also the Company's own design of governors and pipeline valves.

The second article concludes Mr. J. E. Calverley's paper on the "Electrical Equipment of Trolley Vehicle Routes." This section of the paper deals with the control and protection of rectifier sub-stations, wireless interference and current collection.

"Recent Developments in Single Phase Motors" by Messrs. L. Roberts and R. D. Ball describes and gives the characteristics of the various types of single-phase motors which are at present available, including the Lo-ampstart motor recently developed by the Company, and designed primarily to give a single-phase equivalent to a 3-phase squirrel-cage motor with star/delta starting. The authors consider that in the future there will be many examples of single-phase motors being installed, where in the past it was the practice to employ 3-phase motors.

The last article in this issue is entitled "The Application of Diesel-Electric Traction" by Mr. H. H. Andrews. This compares the performances obtainable with diesel-electric and steam traction for various types of railway traffic. The author makes a very strong case for diesel-electric traction as applied to railway shunting work. The importance of shunting work is revealed by the fact that there are no fewer than 3,800 locomotives used for shunting purposes in Great Britain alone, and of the engine miles run annually in Great Britain 20% are used for this class of work.

As manufacturers of the diesel engines, the electrical transmission, and auxiliary machines, the Company hold a unique position in Great Britain, and are able to obtain complete co-ordination between the mechanical and electrical engineers.

900 kW. 550 volts D.C. Rectifier unit on traction service in a sub-station of Bradford Corporation.

The Galloway Water Power Scheme.

By H. L. BAZALGETTE, A.C.G.I., A.M.I.C.E.

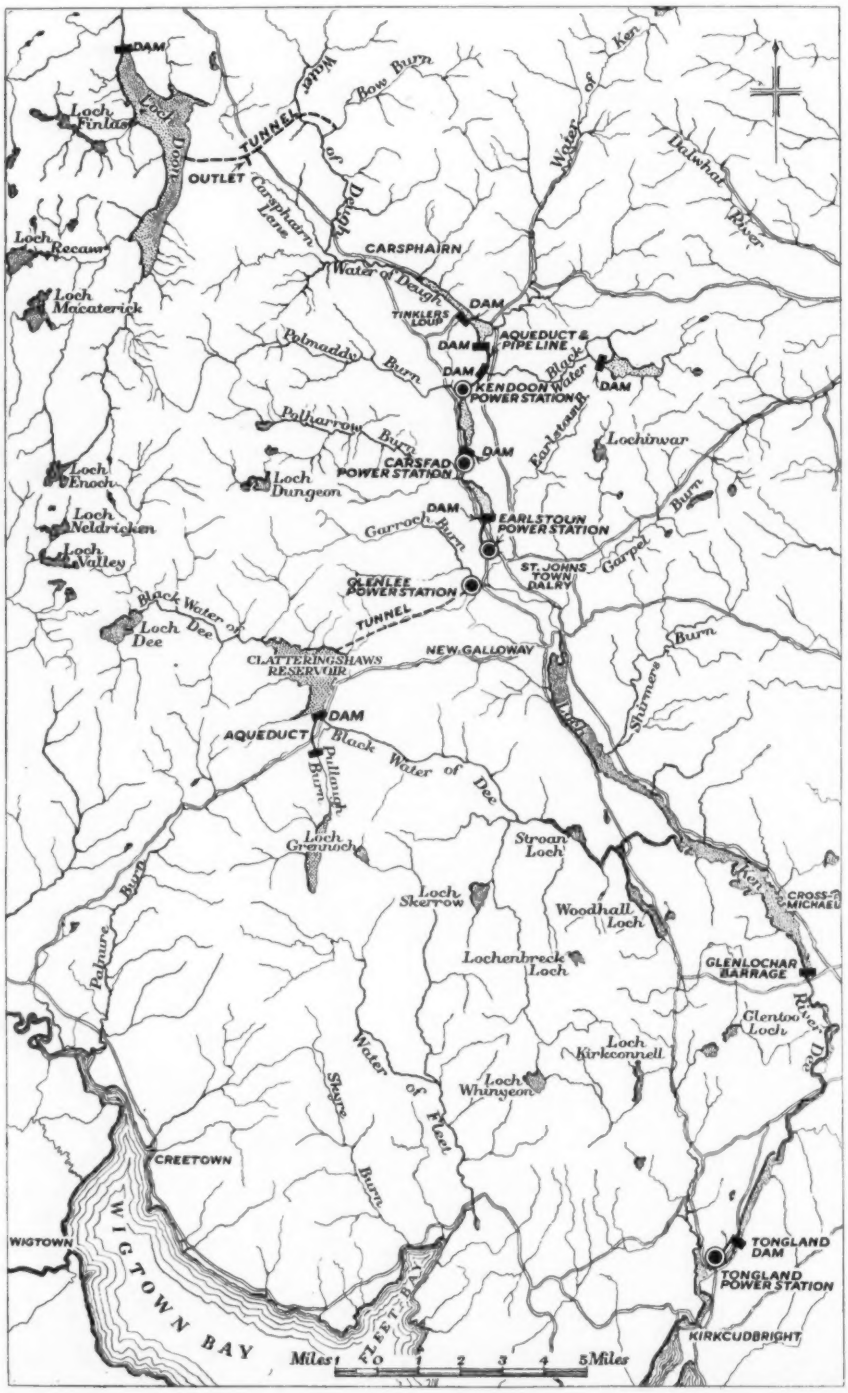
Aerial view of the Tongland Power Station of the Galloway Water Power Company.

Introductory.

The Galloway Water Power Scheme was first considered in 1923 by the late Mr. William McLellan, of Messrs. Merz & McLellan, Consulting Engineers, and a joint study of the possibilities was afterwards made by his firm in conjunction with Sir Alexander Gibb & Partners.

As a result of this investigation a practical scheme was found possible and an Act of Parliament was obtained by The Power & Traction Finance Co., Ltd., in 1929, under which the Galloway Water Power Co. was incorporated with powers to utilise about 400 square miles of the watershed of the rivers Ken and Dee.

The beneficial development of the scheme was primarily due to the establishment of the Grid by the Central Electricity Board. Earlier investigations into the possibilities were made upon the usual assumption that such a project could only be justified if it was operated on a base load, but further study showed that this was very far from being the case, and that, with a comparatively small additional expenditure on plant, a peak load scheme could be produced which would have



Galloway Water Power Company.

economic attractions that a base load system could never possess. A base load plant would have necessitated the construction of large storage reservoirs, the cost of which would have been prohibitive, but the presence of the Grid permitted the power to be fed into it at times of peak load and thus enabled the load factor of the steam stations in the industrial areas of Mid-Scotland and Northern England to be improved.

Nature added a further contribution to this favourable arrangement by virtue of the fact that the maximum amount of water is available in South Scotland in the winter months, during which time the demand for peak load power is the greatest. As the scheme is thus designed for peak load operation the average annual load factor is necessarily low and amounts only to about 20 per cent., though when water is abundant the plant can run at full capacity for long periods.

Thus by close co-operation between the Galloway Water Power Co. and the Central Electricity Board a very economical and flexible system can be secured.

Situation of Works.

The map shown in Fig. 1 gives the main features of the scheme, and proceeding from North to South it comprises the following Power Stations having a total installed capacity of 102,000 kW. :—

	Catchment area sq. miles.	Average nett head ft.	Installed capacity kW.	No. and size of units kW.
2nd Stage.				
Kendoon	152	150	21,000	2—10,500
Carsfad	171	65	12,000	2— 6,000
Earlstoun	193	67	12,000	2— 6,000
1st Stage.				
Glenlee	49	380	24,000	2—12,000
Tongland	396	106	33,000	3—11,000

Loch Doon, which is at the North-West corner of the catchment area, is normally drained westward to the sea by the River Doon. It has therefore been dammed at its outlet to form a reservoir which constitutes the principal storage for four out of the five power stations which comprise the ultimate development, viz. : Kendoon, Carsfad, Earlstoun and Tongland.

In addition to its own catchment area Loch Doon drains by means of a tunnel the catchment area of the water of Deugh and that of its tributary, Bow Burn, and the total capacity of the reservoir thus formed is 2,900,000,000 cubic feet.

Below the village of Carsphairn, dams have been formed across the waters of Deugh and Ken, thereby joining up the two streams into a single reservoir, which constitutes the daily storage for Kendoon Power Station. A short distance below Kendoon the Ken is again dammed to provide storage for Carsfad Power Station, and below that again there is a further dam to impound water for Earlstoun Power Station. These three power stations, which form the second stage of the scheme, are thus all served by the same water.

Glenlee Power Station, which lies just downstream of Earlstoun, is supplied by a reservoir at Clatteringshaws, which has been formed by constructing a dam across the Blackwater of Dee, thus flooding the adjacent land. Water is led to Glenlee by a tunnel and pipeline, and after passing through the turbines, is discharged into the Ken. The combined waters from Earlstoun and Glenlee then flow into Loch Ken, which has been made into a regulating reservoir for Tongland Power Station by the construction of a barrage at its outlet at Glenlochar.

Seven miles farther downstream at Tongland, a dam has been built to form another reservoir or head pond for Tongland Power Station, which is fed by a tunnel and short pipeline.

In the scope of this article, which is primarily devoted to a description of the plant, it is not possible to give more than the above very brief outline of the scheme which it is hoped will present some idea of the manner in which the available water power has been developed. It will be observed that the aggregate installed capacity of the plant is 102,000 kW., of which 57,000 kW. is represented by Tongland and Glenlee Power Stations ; these form the first stage of the development, and are now in full commercial operation.

It is of interest to note that in the execution of the civil works and buildings great care has been taken to do the least possible injury to the natural beauty of the scenery. A study of the aerial view illustrated at the commencement of this article

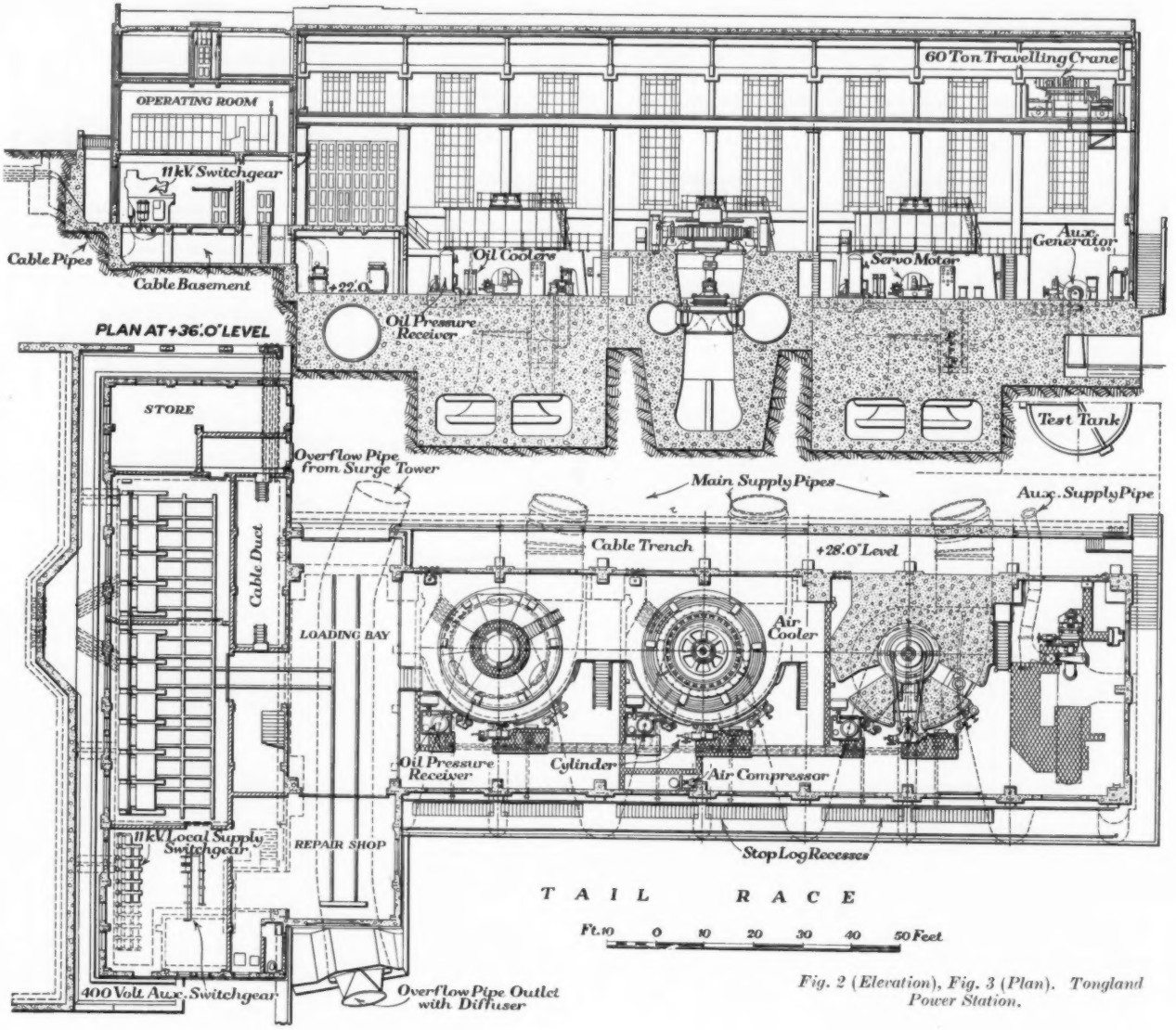


Fig. 2 (Elevation), Fig. 3 (Plan). Tongland Power Station.

will prove that hydro-electric works can be executed with far less detriment to the scenery than many of the familiar, and less useful, objects which now disfigure the countryside.

Plant Contracts.

On the formation of the Galloway Water Power Co., Messrs. Merz & McLellan and Sir Alexander Gibb & Partners were appointed Consulting Engineers for the plant and the civil engineering works respectively, and early in 1932, following upon the approval by the Central Electricity Board of the South Scotland Scheme, contracts were placed with the English Electric Company for the complete equipment of the Tongland and Glenlee Power Stations.

For both stations the contracts comprised the main and auxiliary hydro-electric generating sets together with the whole of the switch and control gear, cables, heating and lighting installations, and the delivery, erection and placing into service of the entire equipment.

These contracts were thus of the comprehensive character admirably suited to our Company, and although portions of the plant were of a design never before executed in this country, the work was of a nature that the Company's works were well equipped to undertake.

The main turbines for Tongland consist of three vertical shaft reaction units, each capable of a maximum output of 17,500 h.p. under a maximum head of 114 feet and running at a speed of 214 r.p.m.

Coupled to these turbines are three vertical shaft 3-phase alternators, each capable of a normal output of 11,000 kW. 0.8 power factor, at 11,000 volts, 50 cycles, and a maximum output of 12,375 kW.

At Glenlee the turbines are also vertical reaction type, each giving a maximum output of 18,800 h.p. under a head of 380 feet at 428 r.p.m., and are coupled to vertical 3-phase alternators, each capable of a normal output of 12,000 kW. 0.8 power factor, at 11,000 volts, 50 cycles, and a maximum output of 13,500 kW.

At each station the contracts included water turbine-driven auxiliary units, there being one set at Tongland of 250 kW. capacity, and two sets at Glenlee, each of 500 kW. capacity.

The switchgear, both at Tongland and Glenlee, comprises metalclad gear for the 11 kV. main and local supply, a 400-volt switch and fuse-switch board for station auxiliaries, and a similar 110-volt board for lighting and heating.

There is also switchgear for the station batteries and charging equipment and a miniature type control board for the 11,000-volt gear.

The whole equipment is of an exceptionally interesting character and will be described in greater detail hereafter.

Transport of Material to Sites.

A matter which required early investigation was the problem of transport to the rather inaccessible sites, of the great mass of material, including some exceptionally heavy and bulky pieces up to 45 tons in weight. Limitations of transport had an important influence on the design of major parts of both turbines and generators, and the matter called for early discussions with the Railway Company, road hauliers and Local Authorities concerned.

As a result of these discussions, the permissible loads, routes, method of conveyance and off-loading points for the sites were decided upon and the smooth handling of the material was assured from the commencement. A favourable arrangement was also entered into with the Railway Company, whereby they undertook the complete responsibility for both rail and road haulage and provision of cranes for transfer from rail to road vehicles, and by this means delays, overlapping and demurrage were eliminated.

In the case of the Tongland rotor centres, each weighing 45 tons, special rail trolleys had to be obtained and conveyance could only be undertaken on Sundays. On the other hand, certain sections of the spiral casings were altogether too bulky for rail transport and had to be taken all the way by road.

Tongland Power House Layout.

Figs. Nos. 2 and 3 give a general idea of the Tongland Power Station layout. The turbine room and switch rooms are entirely separate, and the main cables connecting the two are run in a covered trench outside the upstream wall.

The switchgear building is arranged at right angles to the turbine room and consists of three

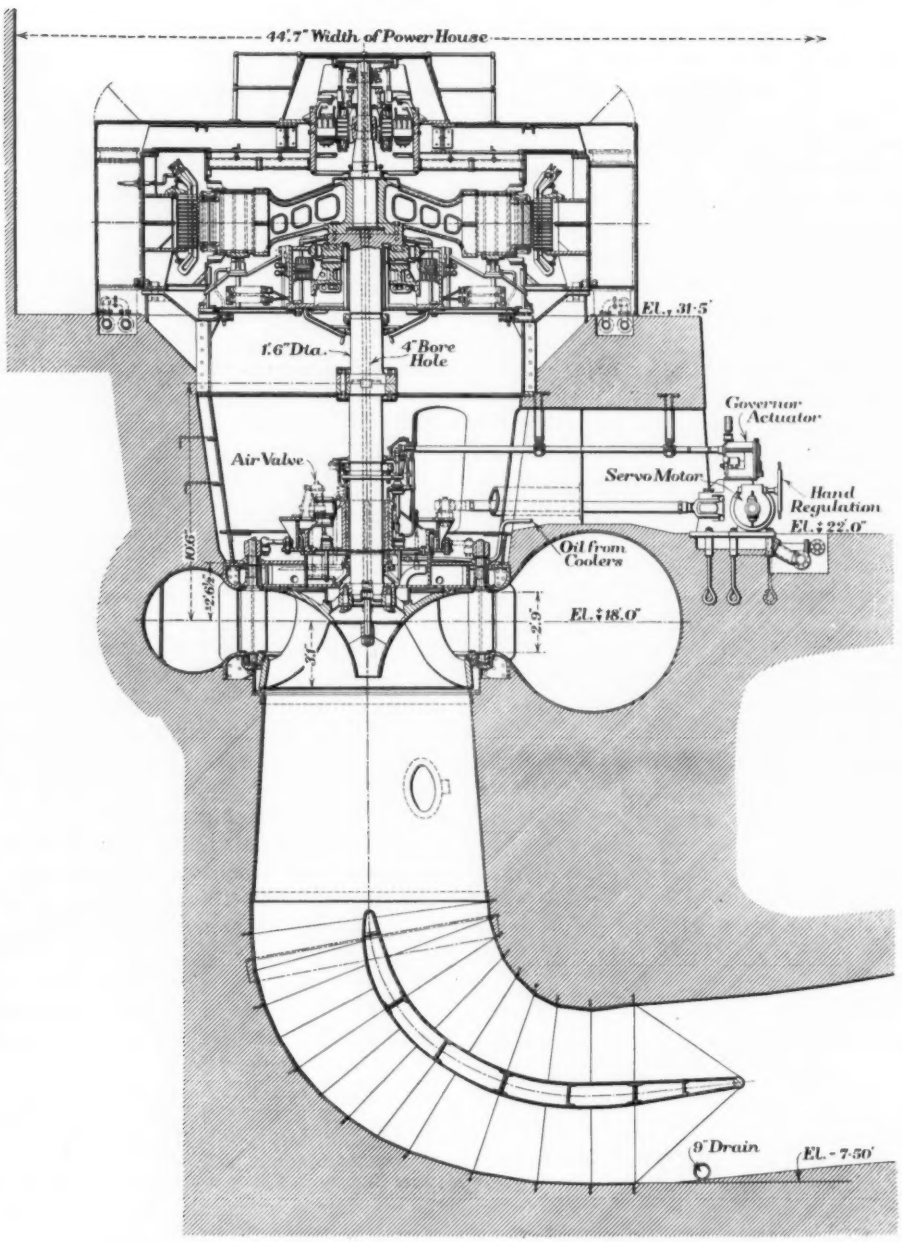


Fig. 4.—Sectional elevation through one of the Tongland Water turbines and generators.

floors and a cable basement. Between turbine room and switch house is the loading bay, which is at the same level as the main 11 kV. switchgear and at a higher elevation than the turbine room floor ; it is, of course, served by the main crane.

The operating room and battery room are above the 11 kV. switchgear and above that again are quarters for staff.

Inspection of the frontispiece and of the cross section shown in Fig. 4 will indicate the turbine room layout. It will be noted that the one floor arrangement has been adopted, i.e., there is no second floor at generator level such as is frequently found in vertical shaft hydro-electric stations.

There are many advantages in the single-floor arrangement, one being that the Power Station crane has access to all parts of the plant and at all levels, whereas with the two-floor arrangement this is not possible. Another important advantage is that a direct drive can be arranged for the governor, whereas with the two-floor arrangement the governor usually has to be placed on the top floor with a gear drive to the turbine-gate regulating mechanism below.

It will be noted that the generator is mounted upon a fabricated steel generator support, and the whole is then surrounded by concrete, strongly reinforced, to form a solid block or pedestal which is in one piece with the upstream wall of the station. This leads to a very solid and rigid construction and, as can be appreciated from the *Frontispiece*, an exceptionally light and accessible turbine and generator room is secured.

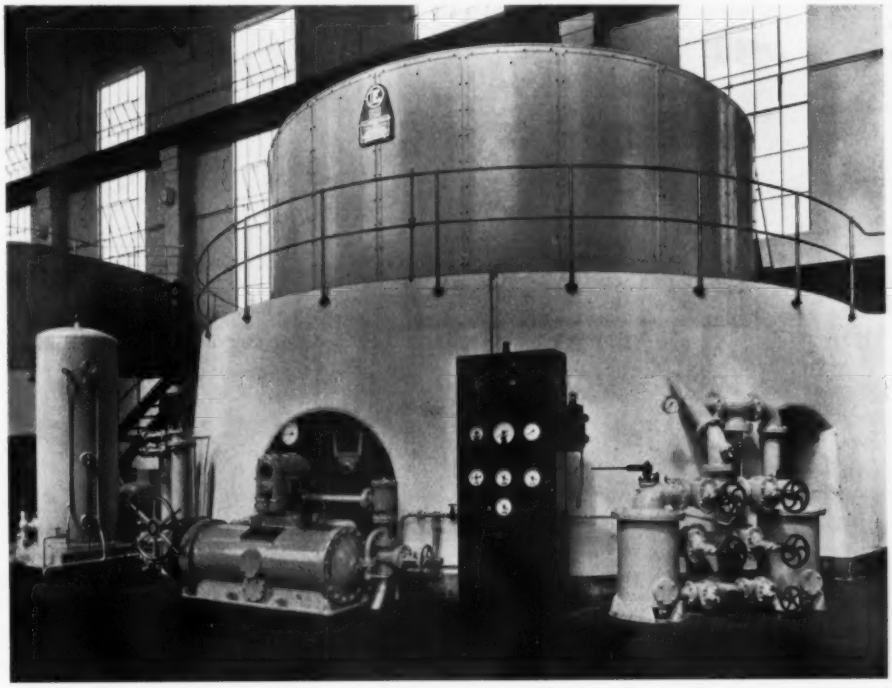


Fig. 5.—One of the 11,000 kW. generating units in Tongland Power Station.

All the auxiliary equipment, such as governors, servomotors, oil pumping sets and pressure receivers, strainers, machine instrument panels, etc., stand on the floor at the foot of the concrete pedestals and are easily seen and operated. Fig. 5 shows one of the Tongland generators with this auxiliary equipment (which will be described in more detail hereafter) at the foot of the pedestal.

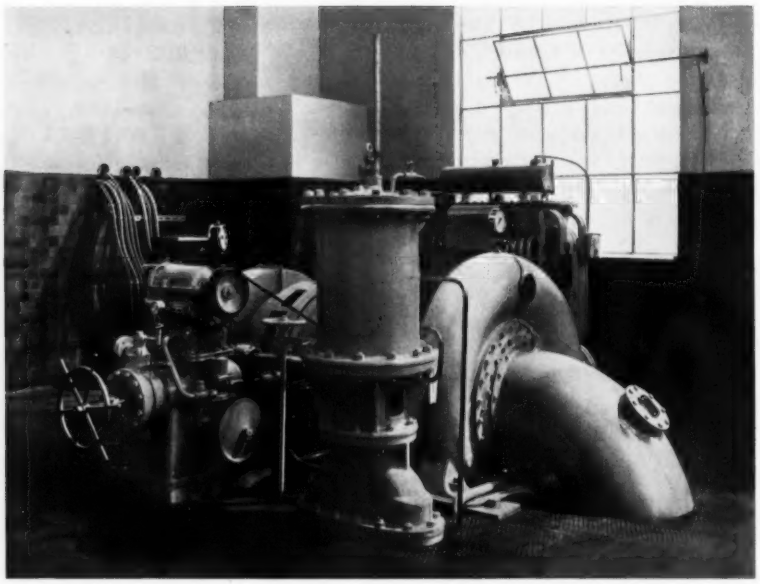


Fig. 6.—250 kW. Turbine-driven Auxiliary Alternator Set.

The turbine-driven auxiliary alternator is situated at the end of the turbine room remote from the switch house (Fig. 3). An illustration of this unit is shown in Fig. 6, and it consists of a horizontal shaft reaction turbine working under a head of 106 feet and driving a 250 kW. 3-phase, 400-volt, 50 cycle alternator at 750 r.p.m.

In the foreground can be seen the oil pressure governor, which is belt-driven from the shaft, and also the main inlet valve.

A study of the cross section in Fig. 4 will show that a vertical shaft plant requires very close co-operation between the plant and civil contractors if the work is to proceed uninterruptedly and smoothly, and this is particularly the case with the layout now described, as the turbine foundations and the generator setting form an integral part of the whole Power House structure. Fortunately, throughout the execution of the present contracts, such co-operation was most fully secured and all contractors worked together to attain the best results.

The aerial view of Tongland Power Station on the title page gives a good impression of its layout and of the country in which it is situated. The Central Electricity Board's 132 kV. sub-station can also be seen in this illustration. The tunnel from Tongland Dam conveys the water to the 100 ft. diameter surge tower, from which it passes through steel pipe lines to the turbines.

The small building between the surge tower and the Power Station, houses the main valves. Within the surge tower can be seen the funnel-shaped top of the overflow pipe, which passes down beneath the Power Station and discharges through the "disperser" which can be seen set in the downstream wall of the station to the left of the turbine draught tube exits. In the event of a surge the overflow water from the surge tower is discharged to the tailrace in the form of a fine spray by this "disperser," which was included in the Company's contract; a more detailed description of this will be given further on in this article.

(This article will be continued in the next issue.)

The Electrical Equipment of Trolley Vehicle Routes.

Reprint of Paper read before the Tramways and Light Railways Association at Llandudno, 6th June, 1935.

By J. E. CALVERLEY, M.I.E.E., Chief Engineer and Manager, Traction Department.

(*Continued from Page 191, Vol. VII, No. 7.*)

To deal with regenerated current the rotary convertor can, of course, have the reverse current relay set higher, and this is now the usual method when rotary plant is installed.

With the normal type of rectifier equipment regenerated current cannot be accepted, and there is consequently an undue rise in line voltage, unless the power is absorbed by another load on the section concerned.

A compromise can be made by tying in a rotary with a rectifier station. By this means the useful field of regeneration is extended and the conductivity increased. The arrangement adopted can only be decided with a full knowledge of the of the local conditions of the power supply and the traffic handled.

Over-voltages cannot be tolerated on a bus—on the lighting circuit, for instance—yet at certain times and under certain conditions the line voltage will tend to rise. As an example, one has only to consider the first bus out or the last bus into a depôt. A bus must be protected from loss of braking following no-volts on the line, and this can be dealt with in two ways, or preferably by a combination of the two. In a rectifier station relays can be provieded which insert resistance across the line, thus providing a load for regenerated current not otherwise absorbed. The most satisfactory protection, however, can be provided on the bus itself by the provision of an over-voltage relay. In the event of the terminal voltage of the regenerating motor rising above a pre-determined figure, connection to the line is broken and the motor circuit is automatically changed to rheostatic braking.

IV.—Sub-Stations.

The tendency to install a larger number of sub-stations has been encouraged by the progress of the rectifier and the increasing availability of a power supply in outlying districts. The rectifier station possesses important advantages which are popularising its use, namely, its silence, compactness, and the fact that little is required in the way of foundations and buildings. These qualities are of special importance in built-up areas.

Attention should be given to the operating characteristics of rectifiers. Their losses are sensibly constant over the whole load range, and as a result a high all-day efficiency is obtained, but at the same time their location and capacity—as with any type of converting machinery—should be selected with a view to keeping them as nearly as possible on full load during operating hours. The possibility of cutting-in or cutting-out certain sub-stations, according to traffic requirements, should not be forgotten, as the rectifier particularly lends itself to automatic control, and this will enable a better individual loading to be obtained. A load diagram will assist greatly in determining the suitability of a sub-station site.

A somewhat different application can be referred to where a rectifier sub-station is used chiefly for the correction of low voltage on severe grades. In such a case it will be found that the average current, during power-on, required by a bus is of the order of 200 amps. or more. The voltage drop of the line will be severe and will not be greatly relieved by regeneration, because over the distance considered—say, one mile—the number of buses may not exceed three or four on both tracks together. The load diagram on the station may not be ideal, having peak to average ratios in excess of 2 to 1, but the installation of a rectifier has the advantages enumerated above, is relatively cheap, and saves distributor copper. Such a station would, in all probability, work in

parallel with a feeder at the other end of the grade and be controlled on the load demand system mentioned below.

No particular comments are necessary on the load characteristics of rotary sub-stations, but some observations on those of a rectifier may be helpful. In the case of outlying sub-stations, or those operating in parallel with others, there is no call for any other than the normal shunt characteristics. This is particularly so for small glass-bulb rectifier units, where overloads should be limited and compounding would lead to the station grabbing such load as may be available. Compounding is only feasible in the case of a large sub-station serving a number of radiating and isolated feeders.

Rectifiers are compounded by means of grid control or by the inclusion of induction regulators on the transformer side. In either case there is a time lag in the operating mechanism, although recent developments have resulted in instantaneous grid response by automatic means. Having regard to the fluctuating nature of a traction load, instantaneous response would seem to warrant consideration, remembering that it can only be economically applied to the larger units, on which the load is more uniform.

Control.

There are three methods of control, namely :—

Supervisory control,
Time switch,
Load demand.

The first is expensive and finds little application in the system under consideration ; it is more suited to large power net works. The second method has the merit of cheapness and simplicity, and is particularly suited to conditions where a regular schedule is operated. The time-switch control merely starts up and shuts down the station at certain times. The third system results in greater economy of operation and has the advantage that within limits abnormal conditions of traffic can be dealt with automatically. The load demand system starts up the station on under-voltage and closes it down on under-load. In order to avoid unnecessary starts and stops, the times of incoming and outgoing are different, being, say, half-a-minute and a quarter-of-an-hour respectively. The control of the under-voltage relay may be thermal (cumulative effect), while that of the underload is generally by means of a time switch. An additional refinement to the latter provides for continued operation should the load again increase during the operation of the time switch.

Protection.

It is usual to provide high setting A.C. overload protection with the inverse time characteristic on the H.T. side of the converting units. The operation of the overload protection causes a lock-out of the unit and necessitates hand resetting. The rupturing capacity of these breakers is solely dependent on the kVA available from the main supply system at the point in question.

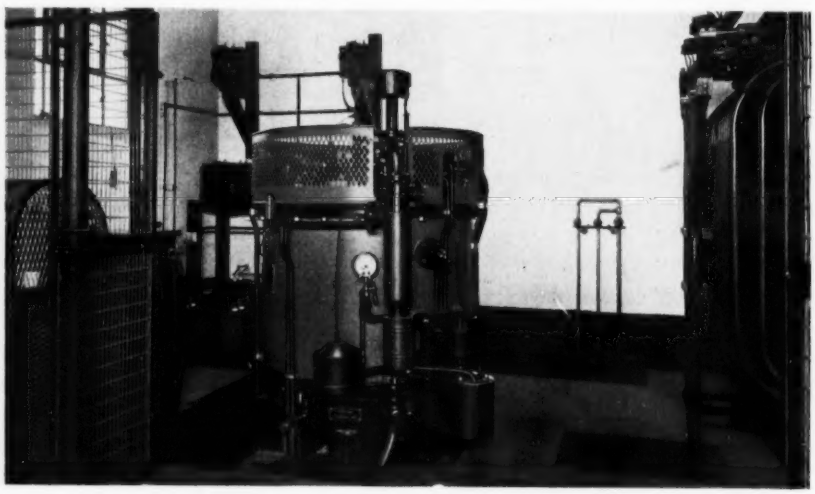


Fig. 1.—"English Electric" 500 kW. steel tank rectifier unit in a traction sub-station.

On the D.C. side of the converting units a distinction should be drawn between the smaller and larger units. In the case of glass-bulb rectifier stations it is only necessary to provide overload protection with auto-reclosing. Such stations are usually unattended and may feed directly on to the line. A criticism has been made against the auto-reclosing feature, for if the fault is not immediately cleared, and the equipment closes down, it becomes necessary to send a man to the station. This difficulty can be overcome by the provision of restarting relays controlled by pilot wires, which can be made accessible at section pillars or other convenient points.

Fig. 2.—"A.E.C.-English Electric" single-deck, 32-seater Trolley Bus supplied to the Notts. and Derby Traction Company.

When the larger sub-stations have rotaries or metal-tank rectifiers operating in parallel with other plant directly on the busbars or through the D.C. system, protection should be by high-speed reverse current breakers. Overload protection is confined to the individual feeders, for it is clearly undesirable to shut down the supply on account of one defaulting feeder. The overload feeder protection is provided with auto-reclosing gear. Where the number of feeders is small, so that their capacity is more comparable with that of the converting units, it is not uncommon to give the circuit-breaker an opening characteristic on forward overload in addition to the reverse feature. In this case auto-reclosing must also be incorporated, and the number of reclosing operations made in excess of those of the feeder, which are usually three, before locking out. A " feeling out " feature is not uncommon in conjunction with feeder breakers. With this scheme a resistance across the breaker enables a limited current to be fed into the defaulting circuit, and the condition thereby noted. This feature is probably more effective on a trolley bus system having insulated wires on the positive and negative side than on a tramway circuit. When a healthy condition is restored on the feeder, the breaker automatically recloses. Naturally, a number of combinations in the control and protective circuits can be used, depending on local conditions and preferences.

The question of the single or double-pole switches for a trolley bus system is a matter largely of preference. There is no essential difference from the tramway system in the matter of having an earthed point at the sub-station, whether rotaries or rectifiers are used. The fact, however, that there is a larger negative drop compared with the tramway does give cause for considering double-pole switches.

The question of high-speed and low-speed breakers is sometimes raised. Naturally, the former gives the finest possible protection, but it is expensive. Medium-speed breakers have been found adequate for smaller equipments and are relatively cheap. It is purely a matter of cost, for in the case of a small rectifier station, for example, a high-speed breaker would amount to approximately 10 per cent. of the total cost. An

additional point in favour of the high-speed breaker should be mentioned in connection with wireless interference, for the quicker the break the less serious are the resulting disturbances.

Finally, with regard to metal-tank rectifiers, although they cannot normally take a reverse current, reverse protection must be provided in the comparatively rare case of an arc back. Arcing back may be caused by severe overloads, and, under certain conditions, such as afforded by parallel operation, an arc may be struck and maintained in the reverse direction, namely, from the cathode to the defaulting anode. This is equivalent to a reverse D.C. short-circuit current, to which the transformer winding offers no impedance beyond its ohmic resistance. This protection is not necessary in the case of glass-bulb rectifiers, for they are protected by fuses in the anode leads from the transformer.

Protection Against Lightning.

Due to the absence of severe lightning storms in this country, the protection has taken the same form as on a tramcar, namely, of the disc and gap type. The arrester is connected between the positive and negative trolley leads and forms a by-pass to the power circuit, the latter being further protected by the wireless chokes, which are in series with the bus equipment. At the same time, it should be mentioned that a large number of buses are operating without arresters, and in this case the lighting circuits are used as a non-inductive by-pass to the main power circuit, the personnel on the bus usually having instructions to switch on the lights on the approach of a thunderstorm. Where low-tension lighting sets are installed the lamps cannot provide a resistance leak in the power circuit, and it is advisable to fit suitable lightning protection. For further safety, and in countries where severe storms are prevalent, it is desirable to protect the trolley wires by means of condensers carried on the trolley standards—separate condensers fitted with discharge gaps being connected from the negative and positive wires to earth.

V.—Wireless Interference.

A great deal of investigation* has recently been carried out by the B.B.C., the G.P.O., and others, so that it is only necessary to make a brief summary of the results with the object of promoting discussion of individual experiences and suggestions.

In the first place, it is as well to realise that, of all the complaints regarding interference received by the G.P.O. in 1933, less than 10 per cent. concerned traction. Furthermore, much can be

* *E.A.I.R.A. Ref. M/T39, "The Magnitude of Radio Frequency Disturbance from Trolley buses and the Use of Condensers and other devices in its Suppression."*

Fig. 3.—"A.E.C.—English Electric" 60-seater Trolley Bus as supplied to Newcastle Corporation.

done by the listening public themselves to avoid interference, namely, by better location and screening of their receiving equipment.

The trolley line can be treated by connecting condensers between the two wires. Two 1,500 volt 0.5 m.f. condensers in series, with the mid-point earthed, very appreciably decrease the interference on the long-wave band, and, in conjunction with radio chokes on the bus, the interference is reduced to within reasonable limits. Such groups of condensers are usually spaced at intervals of a quarter of a mile along the line. In effect, this is the same arrangement as that provided for lightning protection, and the apparatus can therefore serve a dual purposes. An alternative proposal is to install condensers without the additional precaution of trolley bus chokes, the spacing in this case being reduced to 220 yards. The relative cost of so equipping a mile of double track overhead at 220-yard intervals appears to be between two to two-and-a-half times that of fitting a bus with a pair of double-hump radio choke coils.

Fig. 4.—"A.E.C.—English Electric" 50-seater Trolley Bus as supplied to Portsmouth Corporation.

The method of current collection from the overhead system has been largely blamed in the past for causing disturbances, but it is now evident that there are other sources of interference whose effect is far more severe.

Experience in this country indicates a definite improvement with the use of a sliding shoe, as compared with a trolley wheel, and this is particularly the case where the overhead suspension has been specially designed for sliding collection. The standard tramway suspension is not best suited to the use of a shoe, but a number of installations are at present being adapted for its use.

It is interesting to note that observations made on the Continent† show that it is the weak currents of the order of 2 or 3 amperes which cause most disturbance, so far as the collector gear is concerned. This is attributed to the fact that with trolley wheels there is apt to be sparking, as opposed to arcing, and the use of a sliding shoe largely overcomes this trouble.

The major source of interference is due to the bus equipment, namely, commutation of main and auxiliary motors and contactor operation, and while the progress of design naturally tends to improve matters, it cannot entirely eliminate the cause.

Two methods of dealing with the equipment have received consideration. The first is the use of stopper coils, which possess the advantages of simplicity and cheapness and which can readily be applied to existing vehicles. The second method endeavours to reduce interference at each source of disturbance. The chokes or stopper

† *"T.L.R. and T.A. Journal," No. 382, October, 1934. M. J. Peridier, p. 5472.*

coils consist of flat coils of strip copper without appreciable impedance to the normal load current, but possessing considerable impedance to currents of radio frequency. The early coils had sufficient impedance to reduce very greatly the interference to broadcast reception of waves up to about 500 metres, but they were ineffective on the long-wave band. In addition, they added considerable extra weight to be carried on the bus ; the early types weighing approximately 60 lbs., though to-day the use of aluminium is largely responsible for halving this figure.

In the course of the past year the Electrical and Allied Industries Research Association has continued work on these suppressors in conjunction with the Post Office authorities, the manufacturers and the British Broadcasting Corporation. These experiments have resulted in the design of the so-called double-humped chokes, which give a higher impedance on the long-wave bands, in addition to the protection on medium-wave bands previously obtained. The impedance of the single-humped chokes is of the order of 10,000 ohms on wave lengths in the neighbourhood of 300 metres, falling to about 5,000 ohms at 240 and 420 metres. The new coils have an impedance of over 5,000 ohms at 270 and 420 metres, as well as from about 1,200 to 1,600 metres.

Additional suppression is obtained by the provision of filter circuits across the terminals of the offending items. Some improvement has also been noted by the transposition of field coils from the negative to the positive side of the motor armature, or by connecting the armature between two halves of the field system, and screened wiring is also adopted in some cases. The methods, however, can only be considered as ameliorative, and the arrangement of stopper coils, consisting of double-humped chokes in positive and negative leads, appears to be the most satisfactory solution.

VI.—Current Collection.

In addition to considerations of wireless interference, the adoption of the slider head in preference to the wheel is due to a number of other reasons, as follows :—

(1) *Reduction of noise.* Since the trolley bus is comparatively silent, noises hitherto unnoticed become magnified and cause undue annoyance. Such is the case with trolley wheels.

(2) *Practically sparkless collection.* This is advantageous both to trolley wire and slider, for pitting is a defect of the wheel. The slider and wire should acquire a well-burnished surface.

(3) *Dewirements less frequent.* The average figure for wheels appears to be about 6 per 10,000 miles for trolley buses as against 1 per 10,000 miles for the tram-cars. The slider has reduced the trolley bus dewirements to approximately the latter figure.

(4) *Lightness.* The shoe is about 30 per cent. lighter than the wheel and renewals cost less.

Fig. 5.—Trolley Bus Shoe Current Collector.

The key to successful slider-head operation is lubrication, and considerable research is being undertaken in this country with a view to finding the most satisfactory arrangement. Self-lubricating heads are now on test, but it is too early to say whether these are completely successful. Of the external methods, the spraying

of graphite in a volatile solution has been tried out, generally with satisfactory results, and fuller tests, in which the trolley wires are brushed with oil from a tower wagon, are now being undertaken. As far as can be ascertained, the life of a slider shoe is of the order of 2,500/3,000 miles for the positive shoe and 2,200/2,500 for the negative.

In the case of trolley wheels, there is a problem to meet on account of the higher speeds and increased side wear in trolley bus operation. This can be met by increasing the wheel diameter, but a limit is set by the weight involved and the leverage due to side wear. The maximum wheel diameter in common use is 5 in., but certain operators prefer a 4 in. wheel, due to the reduction in weight of the head. The shape of groove also has a bearing on the performance, and on one large trolley bus system the inner walls of the wheel flanges at the rim are made parallel, and this, it is claimed, has been effective in reducing dewirements to 3 in 10,000 miles.

Where slider heads are used the trolley wire must be lubricated throughout its length, and this is the fundamental difference in operation between shoes and wheels. For this reason it is quite unsuitable to intermix buses fitted with wheels and sliders.

Recent Developments in Single Phase Motors.

By L. ROBERTS, M.I.E.E., Manager Industrial Sales and Engineering Department
and R. D. BALL, A.M.I.E.E.

(*Reprinted from "The Electrical Review," 20th December, 1935.*)

Introductory.

A notable advance in recent years in single-phase motor design has been the introduction of capacitor motors, which are available not only in fractional horse-powers but also as large slip-ring machines up to 50 h.p. with starting torques and starting currents similar to those of three-phase slip-ring motors of the same powers and speeds. The capacitor motor has become a practical proposition only since the reduction in cost and the great increase in reliability of condensers (the latter having been greatly influenced by the radio industry).

With fractional-horse-power capacitor motors there is always a temptation (on the ground of cheapness) to supply electrolytic condensers. Such condensers have been used in great numbers in the United States, but there the usual single-phase voltage is 110, whilst in Gt. Britain it is 230; this is one of the main reasons for the difficulty experienced in this country in obtaining a satisfactory electrolytic condenser. In the present state of the art of design of small condensers for 230-V supplies, we believe that it is better to err on the safe side and pay a little more for a paper dielectric, solid-filled condenser. Electrolytic condensers can be made for short-time ratings only, whereas for large capacitor motors the condensers are left in circuit all the time.

In the past the single-phase motor was generally looked upon as possessing poor starting and run-up torques, and as being heavy and costly; for outputs above 5 h.p. even a repulsion-inducton motor did not meet all requirements in these respects.

Fig. 1.—Large Single-Phase Motor with Pulley.

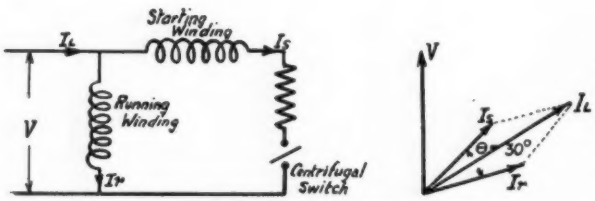


Fig. 2.—Connections and Starting Vector Diagram of a Split-Phase Motor.

The stators of the first single-phase motors were provided with a running winding and a second winding at 90 electrical degrees to it. This second winding, known as the starting winding, is either of the high-resistance type or is in series with a high resistance externally, or else an inductance is inserted in order to provide a difference in phase between the running-winding and starting-winding currents. This type is known as the split-phase motor.

The starting torque is obtained by a combination of the rotor currents induced by the running winding and the flux created by the starting winding and *vice versa*. The torque is, therefore, proportional to the flux and current, that is, to the product of the running-winding current (I*r*) and starting-winding current (I*s*), taking into account their in-phase components.

We therefore have torque = K I*r* I*s* sin θ, which becomes a maximum when θ equals 90°, K being a constant depending on the size of the machine, and θ the angle between the running-winding and the starting-winding currents. Fig. 2 illustrates the circuit and the starting vector diagram of a split-phase motor.

Owing to design limitations, the angle θ cannot usually be arranged to exceed 30°, and the torque with this type of motor cannot, therefore, exceed half the maximum obtainable theoretically; at the same time, the resultant line current I$_L$ is not very far short of the arithmetical sum of I*s* + I*r*.

In smaller split-phase motors, the extra resistance is incorporated in the starting winding itself, and a centrifugal switch cuts out the starting winding when the motor is up to speed. Squirrel-cage motors are suitable up to about ½ h.p., and considerable advances in design have resulted in good starting and accelerating torque, freedom from crawling and silence of operation. For larger squirrel-cage motors, up to about 15 h.p., a graduated-resistance starter is used which places the two windings in series (with a resistance in shunt to the starting winding), but here again the phase split is limited.

Repulsion-Induction Motors.

For outputs up to about 5 h.p. the repulsion-induction motor was very popular a few years ago, being the only single-phase motor which would develop a good starting torque. For sizes of from 1 h.p. to 5 h.p., however, attention to the commutator and brushes was required, while its power factor was poor and its maximum duty was limited to about 10 h.p.

Fig. 3.—Pipe Ventilated, Vertical Spindle, Slipring, Single-Phase Capacitor Motor.

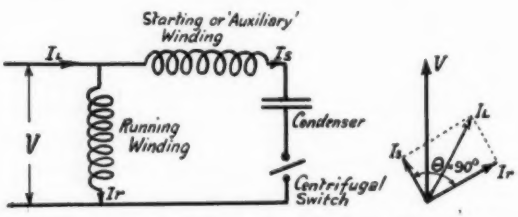


Fig. 4.—Connections and Starting Vector Diagram of a Capacitor Motor.

Capacitor Motors.

Phase-splitting by means of condensers can now be performed at a lower cost than hitherto, and the capacitor type motor has therefore been developed. Fig. 4 shows the circuit and the starting vector diagram for the capacitor motor. As the angle of θ can be made 90° by suitable design, the starting torque can be raised from $\sin 30° = 0.5$ (as in the split-phase type) to $\sin 90° = 1$; i.e., while the starting torque can be doubled, the starting current is only the geometrical sum.

The capacitor design has enabled machines of several types and of much larger horse-power to be developed than was possible with the repulsion-induction motor. The accompanying table, which gives approximate particulars of single-phase motors available for 50-cycle systems, will enable the type of motor most suitable for a particular duty to be chosen by the prospective user.

Characteristics of Various Types of Motors.

Split-phase Squirrel-cage Type.—The split-phase squirrel-cage motor is the simplest type. For small machines automatic starting, and for larger machines, up to about 15 h.p., non-automatic starting can be employed. This type inherently takes a fairly large starting current and develops (especially in the larger sizes) a relatively small starting torque.

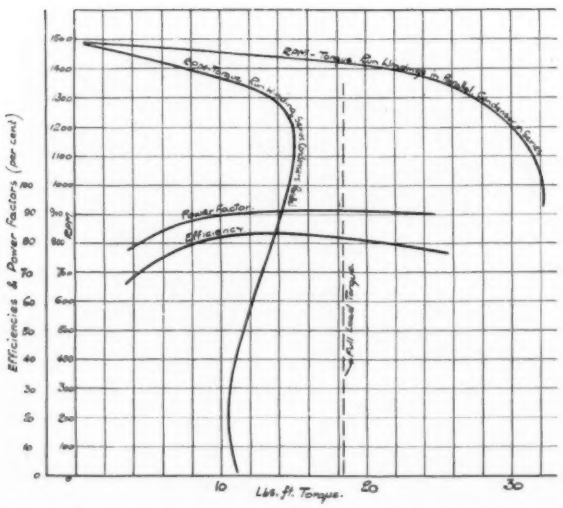
Fig. 5.—Enclosed ventilated single-phase slipring capacitor motor.

Squirrel-cage Capacitor Motors.—Squirrel-cage capacitor motors up to about 30 h.p. can be made with a reasonable starting torque, without taking an excessive starting current. Although in some cases the starting torque developed by a repulsion-induction motor is higher and the starting current is somewhat less than for a squirrel-cage capacitor motor of the same h.p. and speed, the latter may cause less disturbance on the line owing to its better speed-torque characteristic ; i.e., there is no negative kink in its speed-torque characteristic as there is with some repulsion-induction machines.

"Loampstart" Single-phase Squirrel-cage Capacitor Motors.—A form of squirrel-cage

SINGLE-PHASE MOTORS FOR 50 CYCLE SYSTEMS.
APPROXIMATE STARTING TORQUE AND STARTING CURRENT.

H.P.	Type of motor.	Starting torque/ f.l. torque.	Starting current/ f.l. current.	Usual No. of poles.		Method of start.
				200 to 250 V.	260 to 480 V.	
1/10th to ½	Squirrel-cage split-phase.	1.5	6 to 7	4	Not suitable.	Direct on line.
1/10th to 1	Squirrel-cage capduction.	3.0	5 to 6	4	Not suitable.	Direct on line.
1/5th to 2	Repulsion-induction.	3.0	4	4	Not suitable, generally.	Direct on line.
1 to 15	Squirrel-cage split-phase.	0.3	2 to 2½	4, 6 & 8	4, 6 & 8	Non-automatic graduated resistance starter.
1 to 30	Squirrel-cage "Loampstart."	0.45	1.6	4, 6 & 8	4, 6 & 8	Non-automatic double parallel-series.
1 to 30	Squirrel-cage capacitor.	1.5	4 to 6	4, 6 & 8	4, 6 & 8	Non-automatic parallel-series.
1½ to 50	Slip-ring capacitor.	1.0 1.5	1½ to 2 2¼ to 3	4, 6 & 8	4, 6 & 8	Non-automatic parallel-series and rotor starter.



Starting current (21 A), 97 per cent. of full load; starting torque, 60 per cent.; run-up torque, 56 per cent.; max. running torque, 80 per cent.

Fig. 6.—Performance curves of a 4-pole, 5 h.p. "Loampstart" squirrel-cage motor (230 V, 1,420 r.p.m., 21·8 A full load), starting with running windings in series, condensers in parallel.

capacitor motor that has been designed primarily to give a single-phase equivalent to a three-phase squirrel-cage motor with star-delta starting is the "Loampstart." By regrouping the running winding from series at starting to parallel when running, the current drawn by the running winding is reduced to about a quarter during starting, all the starting kVA being retained in the form of torque.

The auxiliary phase winding takes full-load current (approximately) and is displaced by about 90° from the running-winding current with the usual values of starting condensers in circuit. The net effective motor-starting ampere-turns are therefore reduced to half, and the starting current is about 30 per cent. of that taken for straight-on starting, the starting torque being about 45 per cent. of full-load torque. Fig. 6 shows the performance curves of a 4-pole 5 h.p. "Loampstart" squirrel-cage motor.

Slip-ring Capacitor Motors.—The slip-ring capacitor motor gives similar figures to the three-phase slip-ring type for starting torque and current, and can be made up to 50 h.p. As in many instances standard three-phase parts can be embodied, the standard enclosures for three-phase motors can be used.

Conclusion.

Whilst the condenser used with a capacitor motor does help the power factor to a certain extent on single-phase circuits, its main function is to produce the necessary phase displacement between the running and the starting currents and not to correct power factor. We have no doubt that in many instances single-phase motors will be installed in the future where in the past it has been the custom to employ three-phase motors.

Fig. 7.—Small "Loampstart" single-phase motor with pulley and slide rails.

The Application of Diesel-Electric Traction.

By H. H. ANDREWS, M.I.Loco.E., A.Inst.T.
Manager, Traction Tendering and Contracts.

Fig. 1.—Erecting shop for Diesel-electric Locomotives at the Company's Preston Works.

The developments that have taken place in recent years in diesel-electric equipments for locomotives and rail coaches are such that it can now be said that diesel-electric propulsion for traction purposes has passed through its trial stages and has taken its place as one of the recognised means of operating a railway. If there were any doubt on this point it is only necessary to observe that it is in commercial operation in practically every country in Europe, the United States of America, and in many other countries.

Having passed through the trial stages and established itself as a practical engineering proposition, we may now investigate in what circumstances it is advantageous to use diesel-electric propulsion in preference to steam or to electrification.

During the period of initiation it was, of course, the diesel engine that was on trial. Its application to railway work necessitated a vast amount of new design and development, as the slow speed stationary diesel engine could not be used for very obvious reasons.

As time goes on the diesel engine will no doubt be improved, but we must also allow that at the same time the technical science of the steam engine and of electrical equipment will not stand still. As the diesel engine is the more recent development it is possible that its relative advance may be the greater, but it is also possible, if not

probable, that in the course of time other and still more efficient means of converting latent power into energy will be discovered.

We have, however, as practical people, to take things as they are and leave to our more eminent novelists the shape of things to come. Consequently, the purpose of this article is to consider the scope of the diesel engine in traction as it stands to-day, and further to deal only with that form which uses electric transmission.

The reason for this is that at present there is a line at which mechanical transmission is displaced by electric on the score of first cost, cost of maintenance and renewal, and ease of manipulation. Approximately this line is the region of 250 h.p. units, i.e., a unit consisting of one locomotive or one motor coach, not necessarily one diesel engine. Without entering into the argument as to whether this should be the practical limit or whether it will be the limit for the future, it has been taken as a result of a review of the number of each type of transmission in use, and on this basis a dividing line at about 250 h.p. appears to be generally recognised.

The field of traction may be roughly divided into :—

Suburban traffic ;
Long-distance passenger traffic ;
Branch and mixed line traffic ;
Goods traffic and shunting work.

Taking suburban traffic first, this consists of an intense service requiring high acceleration over short distances between stops. Throughout the world this class of service is distinguished by the fact that there is a heavy load each morning and evening ; so that the stock required during the morning and the evening " rush " hours may be six times greater than is necessary for dealing with the traffic during the rest of the day. Consequently, the technical requirements consist of trains with high overload capacity of motive power, to provide high acceleration, and train units which can be readily increased or decreased in size. The diesel-driven train provides the latter but not the former requirement, for while it is capable of multiple unit operation, its power is limited to whatever power is provided by the diesel engine.

It must be remembered, in considering all diesel problems, that the diesel engine possesses no reserve of power ; it generates and uses its own power simultaneously. The steam locomotive can, during slack periods, build up a certain limited reserve of stored power in the boiler ; an electrified system can, on the other hand, overload its electric motors to over 200 per cent. of their continuous rating and draw relatively unlimited power from the source of supply.

Consider a typical suburban service in which the average distance between stops is $1\frac{1}{4}$ miles and the normal train consists of 8 coaches weighing, with passengers, 337 tons ; such a train would accelerate at about 1.25 m.p.h. per second. On an electrified system the electrical equipment would have a weight of about 37 tons, and the full rate of acceleration would be sustained up to a speed of 24 m.p.h. Eight motors would be employed, and the total weight on the driving wheels would be 110 tons. Momentarily at the peak of acceleration the motors, having a total continuous rating of 1,376 h.p., would exert 2,880 h.p.

To provide an identical performance it would be necessary to install diesel engines capable of giving 3,600 h.p., assuming an overall efficiency of 80 per cent. As this is out of the question, an alternative might be considered of installing diesel engines with a horse-power corresponding to the continuous rating of the motor, viz., 1,730 h.p. The provision of space for this would entail the addition of one more coach. The total weight of the train would become approximately 400 tons against 337, and as acceleration could not be fully sustained up to 24 m.p.h., the time taken would be increased by 20 per cent.

It is hardly necessary to enter into a discussion as to what a steam train would do under these circumstances, and it is universally recognised that no steam train can give an equivalent performance for suburban service.

Next comes the consideration of long-distance passenger traffic. From the point of view of diesel-electric versus steam, this can be considered quite separately from the question of goods traffic ; in comparing both of these, however, with plain electrification there is the essen-

tial difference that plain electrification has to be a comprehensive scheme, and that if a line or an area is electrified it naturally handles both passenger and goods traffic electrically.

There are, both in Great Britain and abroad, many lines and areas which at the present moment are suitable for electrification owing to their density of traffic, and where an area or line is suitable for electrification there is no doubt that this affords the most efficient and economic method of working, and performances superior to that obtained by steam or diesel-electric will be possible.

To attempt to carry the comparison further, however, would involve much too detailed an examination of particular localities which could not be dealt with in a brief article, so that from now onwards the study of the scope of diesel-electric traction will be a comparison between it and steam practice, leaving it to be understood that there are areas where electrification is preferable to both.

There are manifestly certain advantages in the diesel-electric locomotive. It is ready for use at any moment, whereas the steam locomotive has to employ labour to raise steam. Fuel is only used for the exact period of running and is not being wasted during halts and at the terminus.

On present-day prices for coal and diesel fuel such figures as can be obtained go to show that there is a considerable economy in the use of diesel fuel. One point in which the steam locomotive has an advantage is that it provides inherently for the heating of the train, whereas on a diesel-driven train it is necessary to provide an auxiliary boiler. On the other hand, the diesel-electric unit compensates for this by the much smaller weight of fuel carried, and its easier storage. A diesel-electric locomotive can carry its own fuel, while an express steam locomotive has to haul a tender which, when half full, adds 15 per cent. to the locomotive weight.

The comparison, however, of a diesel-electric locomotive with a steam locomotive consists of balancing a number of points and operating costs, all of which vary according to the locality of operation, and for which a general case may be difficult to state; when coal is dear or water supply unsatisfactory a strong case can be made for the diesel-electric locomotive.

We have grown accustomed to think of long-distance trains in terms of a locomotive hauling

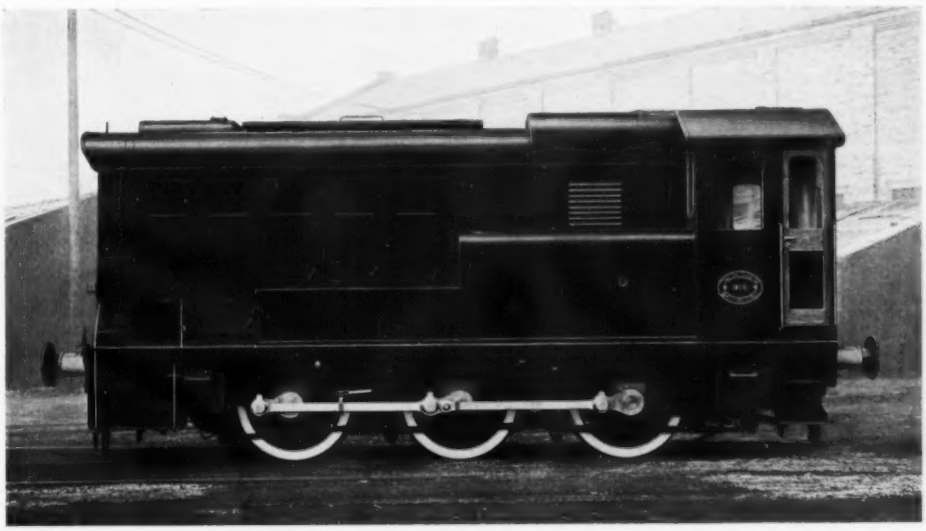


Fig. 2.—350 H.P. Diesel-electric shunting locomotive.

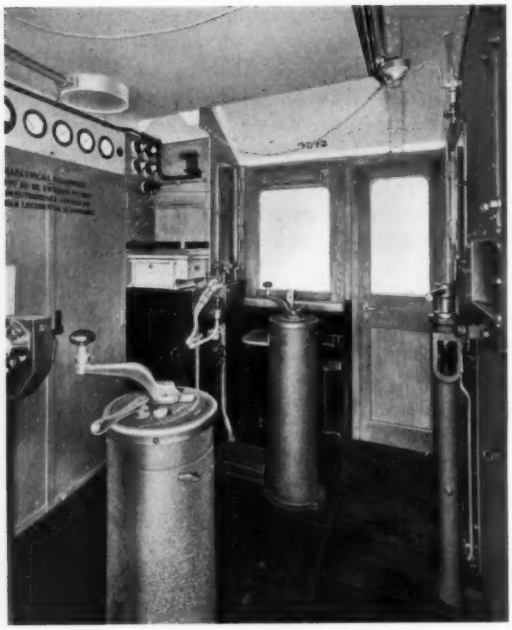


Fig. 3.—Interior of driving compartment of Diesel-electric shunting locomotive.

8 or 10 heavy passenger coaches ; this, however, is not an immutable law, but a condition governed by the necessities of steam locomotive practice. If the motive power can be distributed in the train and still operated from the head of the train, there is no reason why the train should not be made up of two or three units, each consisting of three or four coaches, one of which would be fitted with a diesel-electric engine compartment ; each unit capable of operating by itself but controlled by multiple-unit operation from the leading driving end. This is, of course, the principle of operation of electric multiple-unit stock, and apart from suburban lines it has already been operating successfully on the 60-mile run from London to Brighton, and there is no reason why it should not be equally successful for distances of unlimited length.

This arrangement has the obvious advantage that the weight on the driving wheels is provided partly by the hauled stock, and it is not necessary to provide a heavy locomotive to house the engine power and to provide adhesion for the driving wheels. As was pointed out for suburban stock, the diesel engine compartments will take up a certain amount of space otherwise occupied by passengers, so that a 10-coach train would become an 11-coach train.

A comparison with a normal London to Manchester 10-coach express having a total weight loaded of 504 tons, of which the locomotive and tender weigh 151 tons, shows that with a diesel-electric 11-coach train the total weight of the coaches, passengers and diesel-electric equipment would be 432 tons, so that there would be a saving of 14.5 per cent. in the total weight hauled, although the performance of the train would be identical.

Translating this 14.5 per cent. into fuel consumption, and adding it to the fact that the cost of fuel for a diesel performance is considerably less than that on a steam train, there would undoubtedly be a very big saving in fuel costs.

Having reached this point, the question of high-speed diesel-electric trains enters inevitably. In actual fact the question as to which type of motive power is used has very little to do with the question of high speed, except in its relation to the total weight of the train, where the advantage lies with the diesel-electric as compared with the steam train. High speed is simply a matter of providing more horse-power per ton, coupled with lightweight construction of stock and streamlined coaches.

A century ago 50 m.p.h. would have been considered a high speed ; now it is attained by thousands of individual drivers on the open road. Roughly speaking, therefore, when we talk of high-speed trains to-day we mean trains that on level track can attain speeds of 90 to 100 m.p.h. The introduction of speeds 50 per cent. higher than those to which we have been accustomed will bring into the picture many matters that have nothing to do with the source of the motive power of the train.

Finally, it becomes merely an economic question : high speed means higher cost, higher cost means higher fares. If there is an adequate travelling public willing to pay, then the engineer is quite prepared to go to 10, 20 or 30 h.p. per ton

to provide the motive power, and this can be done with steam, electric and diesel-electric motive power with equal facility.

Consequently, when you have stream-lined your locomotive and your rolling stock and built your stock as light as possible, you are left with exactly the same considerations of the relative merits of steam and diesel-electric motive power as you have in the case of present-day express trains.

The third group consists of branch line mixed traffic, and traffic on lightly loaded lines, particularly abroad. The conditions are so diverse, both economically and politically, that it is impossible to generalise. The advantage will certainly lie with the diesel-electric where coal is dear and water is scarce or of bad quality. At the same time it must be remembered that the diesel engine introduces a new class of maintenance work, a matter which might be of some concern to small railways operating a long distance from the source of manufacture. Further, on lines of this nature the traffic is often too diverse to make it possible to always utilise the motive power in the most efficient manner possible. Heavy locomotives may have to draw light trains because it is not economical to keep a variety of locomotives, and in the course of a day a locomotive may be required to do shunting work, light passenger work and goods work. It is only possible, therefore, to state whether diesel-electric has a definite function after a study of each individual case.

The fourth group of railway services is goods traffic, both heavy and light. This must be a locomotive job so far as relative merits go; it becomes again a plain question of the advantages of the diesel-electric locomotive against the steam locomotive which has already been dealt with.

Lastly there is shunting work; that this is not unimportant is shown by the fact that there are approximately 3,800 locomotives used for shunting purposes in Great Britain alone; of the engine miles run annually in Great Britain, 20 per cent. are used for shunting purposes. For this class of work not only can a case be made for the diesel-

Fig. 4.—350 H.P. Diesel-electric shunting locomotive with side covers removed.

electric locomotive, but an overwhelming case. The operation of a shunting locomotive consists of a vast number of short hauls, a considerable amount of idle time during which full power must be immediately available, high tractive effort, relatively low speed, quick reversal, and continuous operation.

Over an average spell of duty a shunting engine averages 3 m.p.h.; its maximum speed while marshalling trains rarely exceeds 10 m.p.h.

Tractive effort is, of course, a factor of adhesion. For any given adhesive weight electric drive can exert a continuous effort 15 per cent. greater than that of a steam engine at starting, owing to its rotational as against a reciprocal impulsive motion.

Reversal on a diesel-electric locomotive is obtained by operating a small control lever in such a way that the instant the wheels have finished rotating in one direction they can be rotated in the opposite direction, no question of coming to rest on a " dead centre " being possible.

In effect, therefore, a 50-ton diesel-electric locomotive can exert the same tractive effort at starting as a 60-ton steam locomotive, it can accelerate faster up to the 5 or 6 m.p.h. required, it consumes no fuel at all during the time the engine is not running, while the steam locomotive is burning coal.

Apart from these important points, there are two more which outweigh them all.

The diesel-electric locomotive is one-man operated, being provided with a safety device by which, if the driver steps off the control or falls ill, the power is shut off and the brakes are applied, and the driver's sole job is the handling of his locomotive by means of two simple levers and his brake handle.

Secondly, it is vastly superior to the steam locomotive in regard to continuous availability. Actual operation has proved that a diesel-electric locomotive can be on duty for 156 hours out of the 168 that constitute a full week, with a major overhaul of two to three weeks per annum. When the term " continuous operation " is applied to a steam locomotive, as it often is, this does not mean that the locomotive can give a similar performance; it means that it can work up to 48 hours at a stretch and after that requires up to 24 hours to be prepared for service again. On this score alone, therefore, 2 diesel-electric locomotives can do the work of 3 steam locomotives.

Summarising, the writer's general conclusion as to the scope of diesel-electric power for traction at the present moment is :—

(1) For suburban traffic it cannot compete with plain electrification.

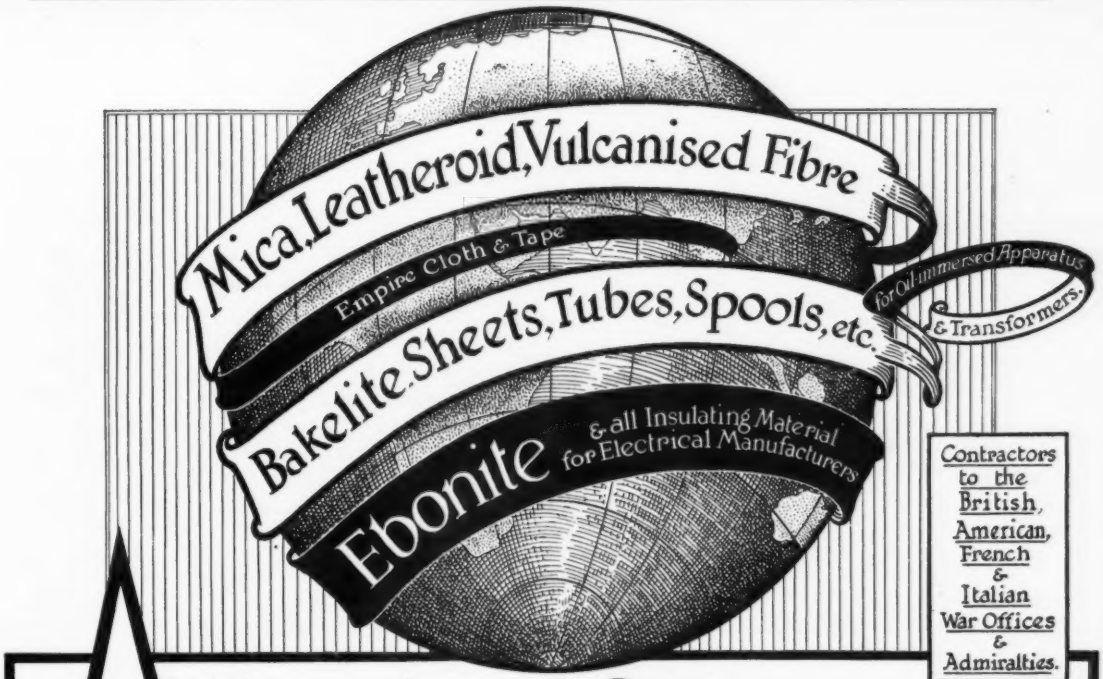
(2) For long-distance passenger traffic it is governed to a great extent by the particular local conditions, but the use of high-speed multiple-unit trains presents great possibilities.

(3) For branch-line and lightly loaded lines abroad, local considerations outweigh all others, and while in many cases no doubt a case can be proved for diesel-electric operation, in others the reverse holds good.

(4) For general goods traffic the question is mainly one of operating cost, and as there are widely different costs of fuel and labour in different areas, again it is impossible to generalise.

(5) For shunting work there is an unanswerable case in favour of diesel-electric traction.

The future of diesel-electric traction is assured, provided it is utilised in the field for which it is suited. This field is so large that it can well be allowed to take its natural place, due to its economic advantages, without attempting to make a case for its universal application.


Mica, Leatheroid, Vulcanised Fibre
Empire Cloth & Tape
Bakelite Sheets, Tubes, Spools, etc.
Ebonite
& all Insulating Material for Electrical Manufacturers
for Oil-immersed Apparatus & Transformers.
Contractors to the British, American, French & Italian War Offices & Admiralties.

Attwater & Sons, Preston, England

Established 1868

MIDLAND STEEL Co., LTD.

— REGISTERED OFFICE —

WEDNESFIELD, Nr. WOLVERHAMPTON

Manufacturers of

BLACK SHEETS, CLOSE ANNEALED SHEETS, CR. & CA. SHEETS, PATENT FLATTENED SHEETS, PICKLED SHEETS, PLATES, $\frac{1}{4}$" THICK & UNDER, CIRCLES, Etc. ALSO SPECIAL DEEP STAMPING & WELDING QUALITY.

— WORKS —

WEDNESFIELD STEEL CO.,
WEDNESFIELD, Nr. WOLVERHAMPTON.
Phone: FALLINGS PARK 31375.

MIDLAND SHEET CO.,
BRICKHOUSE WORKS, WEST BROMWICH.
Phone: TIPTON 1530.

The ABMTM group of machine-tool makers covers the whole field of machine-tool building, giving the engineer at home and abroad a unique manufacturing and sales service.

Apart from the main specialities of the Associated firms, customers have the advantages of the pooled research, the accumulated experience and the entire technical resources of the whole group.

The abundant advantages thus provided by group co-operation will be obvious. The after-sales service provided is of a kind beyond the scope of the single manufacturer.

For further particulars write to:

17, GROSVENOR GARDENS

LONDON——————S.W.1

ASSOC. BRITISH MACHINE TOOL MAKERS LIMTD. TRADE MARK

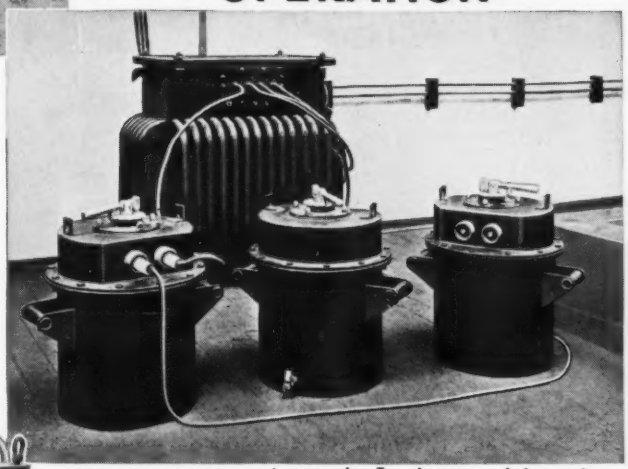
'ENGLISH ELECTRIC'

Part of an installation at a large Shipyard, showing Welding Regulators.

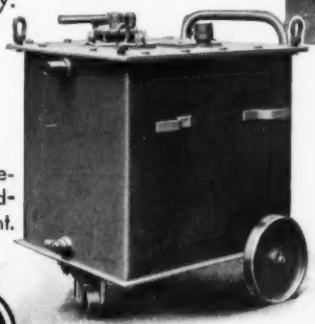
A.C. ARC WELDING EQUIPMENT *for* SINGLE OR MULTIPLE OPERATION

IMPORTANT ADVANTAGES

(1) Low initial cost.
(2) High operating efficiency; approx. 91%.
(3) Static; no rotating parts.
(4) Negligible maintenance.
(5) Suitable for all grades of electrodes.
(6) Stable arc; easy to hold without spluttering.
(7) Good penetration.
(8) Reliability.



6-operator equipment showing the Transformer and three of the six Regulators.



Portable single-operator Welding Equipment.

Our welding engineers will be pleased to advise you on any welding application without obligation. May we show you an equipment in operation?

Write for Publication R. 54

ENGLISH ELECTRIC COMPANY LTD.
Queen's House, Kingsway, London, W.C. 2.
Works: STAFFORD, BRADFORD, RUGBY, PRESTON.

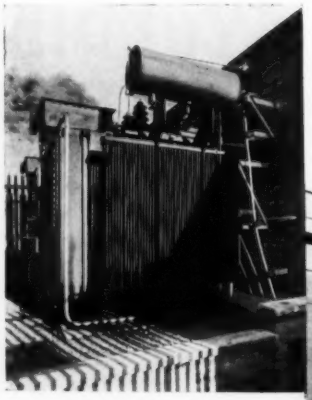
"SILVERTOWN" OILS

FOR

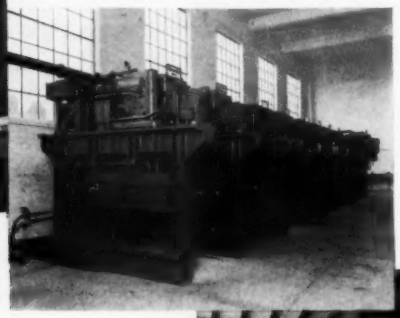
INSULATION

AND

LUBRICATION.



SILVERTOWN TRANSFORMER, SWITCH AND PENETROL HEAVY INSULATING OILS are used, approved and supplied by the principal Transformer and Switchgear Manufacturers. Millions of gallons are in daily use in all parts of the world.



SILVERTOWN LUBRICANTS, for Plant, Machinery and Transport of every description, are known and appreciated for their outstanding value by discerning buyers throughout the world.

Contractors to The English Electric Co., Ltd., and Principal Government Departments, Railways, Municipal Authorities and Industrial Firms.

Silvertown Lubricants LTD.

MINOCO WHARF,
WEST SILVERTOWN, LONDON, E.16.
Send for a copy of Booklet on Electrical Oils.

CRAVEN

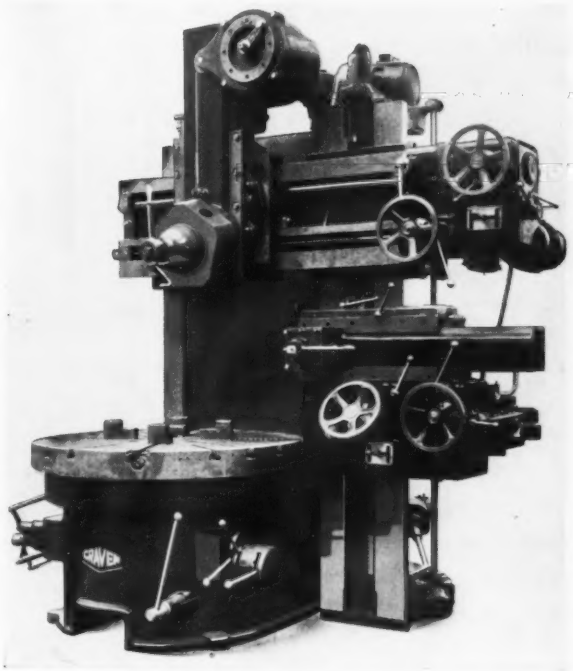
VERTICAL TURRET LATHES

SIZES :—36", 42" and 52".

DELIVERY FROM STOCK.
(Subject to prior sale).

- Self-lubricating table track.
- Single Helical drive to table.
- Centralised control at front.
- Micrometer adjustment to rams in both directions.
- Independent built-in motors to all quick traverse motions.

Write for Brochure N.S. 77.



The illustration shows a machine with side head and turret. Table 52" diameter.

CRAVEN BROTHERS (MANCHESTER) LTD.

REDDISH - - - STOCKPORT.

THERE ARE 2 WAYS OF LEARNING

● One is to seek knowledge on one's own account, to labour with brain and hands and explore fresh fields of thought and accomplishment; in short, to learn by experience.

● The other is to draw from the fount of another's learning, to absorb the knowledge of a fore-runner and apply it to one's own circumstances; in short, to learn by precedent.

In the twenty-third year of the reign of George the Third, Bolton's began to manufacture copper and its alloys and in that sphere of knowledge it has been their privilege, during the most prolific industrial era the world has ever known, to lead the way both in the seeking and in the teaching.

In research and in the application of their researches to industrial problems they have been outstanding for over a century and a half.

ESTABLISHED 1783

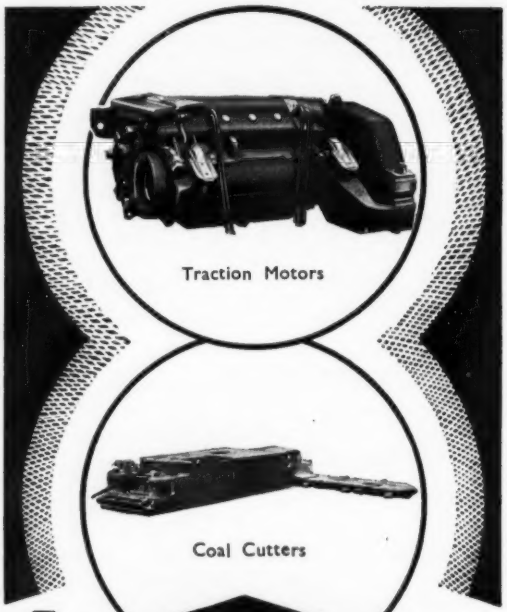
Thomas BOLTON & Sons Ltd

Head Office: MERSEY COPPER WORKS, WIDNES

London Office: 168 REGENT ST. W.1

COPPER · BRASS AND BRONZE

TYPICAL APPLICATIONS



Traction Motors

Coal Cutters

Lewbestos REGD.

(Pure Asbestos Fibre)

INSULATED WIRES

●

COILS WOUND WITH
"LEWBESTOS"
CONDUCTORS
DO NOT BURN OUT
WHEN SUBJECTED TO
HIGH TEMPERATURES

Our booklet on Modern Armature Winding gives practical and technical information. SEND FOR IT NOW!

THE LONDON ELECTRIC WIRE COMPANY and SMITHS, LIMITED

Church Road Leyton, London, E.10.

Tel: LEYTONSTONE 3636 (10 lines) Telg: "LEWCOS, LONDON."

Sockets & Pockets

Not much connection between sockets and pockets at first thought ; but have you ever stopped to realise how small savings on each socket help to swell your pocket. It is really surprising how "Better-Service" Sockets cut your drilling costs.

They outlast ordinary unhardened sockets many times, and will have an astonishing effect on your small-tool bill.

Start ordering "Better-Service" Sockets to-day, and let your pocket feel the benefit.

SEND FOR SAMPLE SOCKET ON APPROVAL.

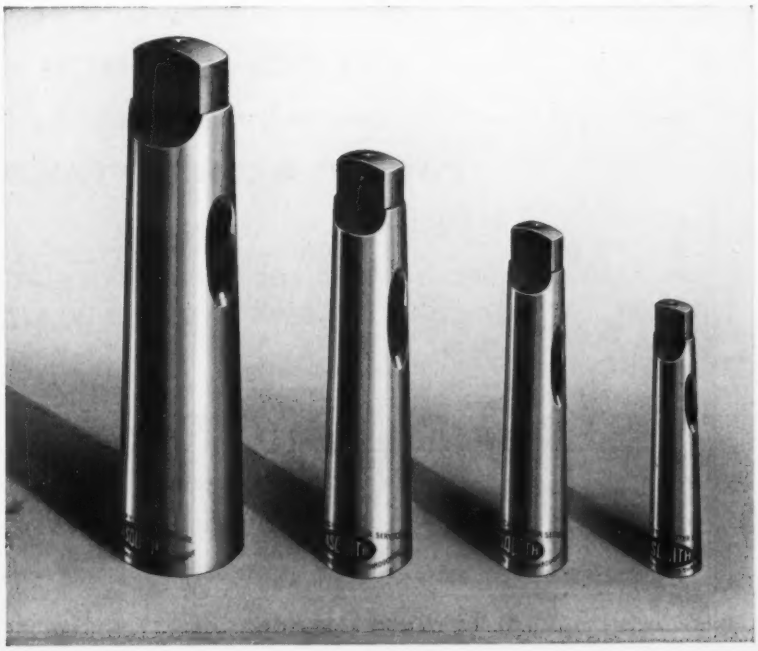
A TRIAL WILL CONVINCE YOU.

REDUCED PRICES.

Inside Taper (Morse Standard)	Outside Taper	Price each s.	d.
No. 1	To suit No. 2 Morse	3	3
,, 1	,, 3 ,,	4	3
,, 1	,, 4 ,,	6	0
,, 1	,, 5 ,,	9	0
No. 2	,, 3 ,,	4	3
,, 2	,, 4 ,,	6	0
,, 2	,, 5 ,,	9	0
No. 3	,, 4 ,,	6	0
,, 3	,, 5 ,,	9	0
No. 4	,, 5 ,,	9	0

ASQUITH

William Asquith, Limited,
Well Royd Works, HALIFAX,
ENGLAND.



Printing of Quality for Electrical & Engineering Trades

STRAKER BROTHERS LTD.
submit, on request, Specimens and Lay-outs for
ILLUSTRATED PRICE LISTS, CATALOGUES AND GENERAL ADVERTISING

Designs prepared for
LETTER HEADINGS
for reproduction by
POWER RELIEF STAMPING

WE INVITE YOUR ENQUIRIES FOR ALL CLASSES OF PRINTING AND STATIONERY

STRAKER BROTHERS LIMITED
"THE BISHOPSGATE PRESS"
194-200, BISHOPSGATE, LONDON, E.C.2
Telephone: BISHOPSGATE 2444 (4 lines)

INDEX TO ADVERTISERS

Asquith, William, Ltd. XVII
Associated British Machine Tool Makers, Ltd. XII
Associated Equipment Co., Ltd. III
Attwater & Sons XI
Babcock & Wilcox, Ltd. I
Bolton, Thomas & Sons Ltd. XVI
Broadbent, Thos. & Sons, Ltd. IX
Craven Brothers (Manchester), Ltd. XV
English Electric Company Limited .... III, XIII, XIX
Hall Bros. (West Bromwich) Ltd. IV
London Electric Wire Co. & Smiths Ltd. XVI
Marelli & Co., Ltd. VII
Mason, E. N., & Sons, Ltd..... VIII
Micanite & Insulators Co., Ltd. VI
Midland Steel Co., Ltd. XI
Siemens Brothers & Co., Ltd. X
Silvertown Lubricants Ltd. XIV
Sterling Varnish Co., Ltd. V
Straker Brothers Ltd. ...XVIII
Taylor Tunnicliff & Co., Ltd. IV
Texas Oil Co., Ltd. XX
Tube Products Ltd. II
Walker, James & Co., Ltd. II
Westinghouse Brake & Signal Co., Ltd. V

All communications respecting Editorial Contents and Advertising Rates should be addressed to The Editor, The English Electric Journal, The English Electric Company Limited, Stafford.

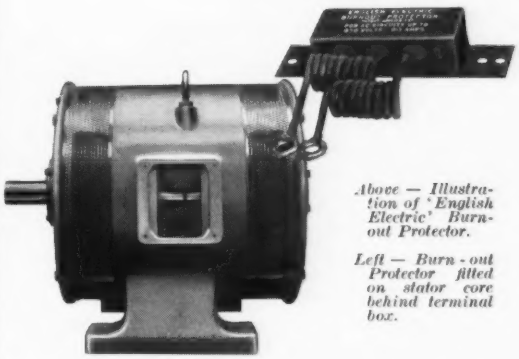
When communicating with Advertisers please mention English Electric Journal.

'ENGLISH ELECTRIC'

BURN-OUT PROTECTORS

for

A.C. MOTORS



Above — Illustration of 'English Electric' Burn-out Protector.

Left — Burn-out Protector fitted on stator core behind terminal box.

Do you appreciate that the present-day system of protection by magnetic or thermal devices fitted to the starter, is only a compromise, and does not safeguard the motor from dangerous overheating, and burning out (even on less than Full Load), due to blockage of the internal ventilating system of the motor with foreign matter.

You can protect your A.C. motors, from approximately 5 to 250 H.P., by fitting an 'English Electric' burn-out protector at the back of the stator core.

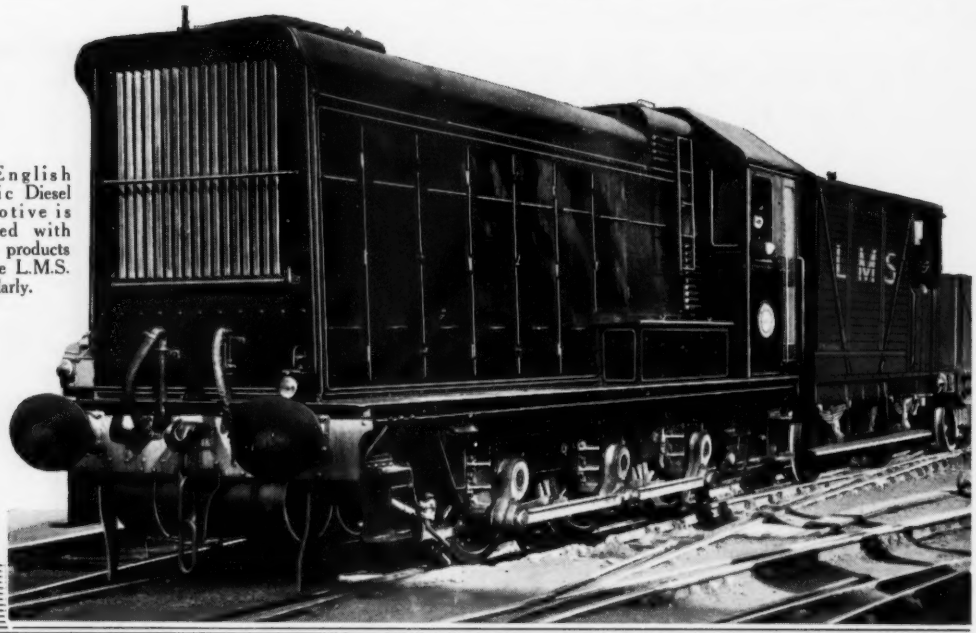
It should be noted particularly that we do not claim that this burn-out protector can take the place of a quick-acting overload device.

Write for Leaflet Q 72

ENGLISH ELECTRIC COMPANY LTD.

Works: STAFFORD, BRADFORD, RUGBY, PRESTON

This English Electric Diesel Locomotive is lubricated with Texaco products which the L.M.S. use regularly.



Use TEXACO tested lubricants and enjoy safety and peace of mind

One of Blackpool's new luxury rail coaches. Also lubricated by Texaco.

More economical, more efficient operation. Dependable lubrication from start-up to maximum speed.

THE TEXAS OIL COMPANY LTD., THAMES HOUSE, MILLBANK, LONDON, S.W.1.

PRODUCERS · REFINERS · DISTRIBUTORS. *One of the largest Organisations in the World.*